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Usability Evaluation Methodology for Public Transport Mobile Ticketing Solutions

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Master Thesis

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To my beloved ones.

Abstract

Considering the increasing mobility levels in urban areas driven by economic, technological and political changes, new mobility trends arise periodically. Public Transport Operators (PTOs) and other entities are concerned with those trends as they mean better quality of urban mobility and opportunity for innovation.

Public transport mobile ticketing solutions are among these innovations. They are new ticketing applications based on customers' mobile devices, which aim to offer a faster and ubiquitous service at minimal investment cost from the PTOs, maximizing consumer's acceptance.

To achieve this goal, as a new technology that requires human interaction, usability evaluations must be carried out. Because a context-specific usability evaluation methodology is believed to be more effective than general ones, this work focused in devising a Usability evaluation methodology for public transport mobile ticketing solutions.

Anda app, a mobile ticketing solution for Porto public transport system, was under final stage of development during the course of this work and served as practical application ground for the produced methodology. A Heuristic Evaluation (HE) and Usability tests were conducted on the application and, as a result, HE demonstrated to be more decisive and the context-specific Heuristics' checklist created during this work was validated. Another eagerly anticipated outcome of applying both usability evaluation methods was a thorough list of recommendations for *Anda*, with mock-ups.

It was concluded that the work has met its objectives because it was able to present, analyze and validate a Usability evaluation methodology for public transport mobile ticketing solutions. During this process, a number of artifacts arose: list of context-specific Heuristics and a Checklist for such solutions, a Usability test form for *Anda*, an analysis and comparison of results of a HE and Usability tests of the referred application, recommendations for the app and further adjustments and discussion over the Checklist.

Acknowledgments

First I thank God, for the blessings that he places around me every day, through which it was possible to conclude this important stage.

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This work benefited from the kind support and participation of the people who accepted to be participants in the Usability evaluations performed in Porto public transport network. Thank you very much for collaborating with the success of this research.

I extend my gratitude to the Faculty of Engineering of University of Porto, especially to the academic and secretariat staff of Master in Services Engineering and Management for their friendliness and dedication to this program. I also thank Nagasaki University, where I was very well received during my mobility semester, and State University of Pará, my alma mater.

Words cannot describe how grateful I am for the love and support of my family during the past two years distant from my hometown; especially for my wife, who accepted to join me in this journey for a Master's degree in a foreign country and was with me when times were harder to endure, and for my father, who always supported my decision to study abroad.

Last but obviously not least, I express my deep gratitude for the precious friendships I settled here in Portugal and the good memories I will carry from now on.

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1 Introduction

Pressure for higher profits, better service offerings and lower costs affect most, if not all, industries, and that includes public transport industry. Therefore, Public Transport Operators (PTOs) look for an answer in mobile ticketing solutions, as they make use of the customer's own mobile device to deliver an innovative, ubiquitous and engaging service, while also minimizing investment costs for the PTO (Campos Ferreira et al., 2014a).

Among other benefits, Fontes et al.(2017) indicate that the main reasons to adopt forms of mobile payments in public transport are convenience and the time-saving prospect, and that the main concerns in adopting it are privacy, interaction and reliability. The aforementioned reasons and concerns are directly addressed in usability evaluation, so its outcomes can be used to increase the adoption and usage of an app.

Mobile ticketing applications for public transport involve many features strongly associated with usability, such as money exchange – hence trust, security and safety –, and can be used in multiple contexts. However, there have not been identified researches concerning context-specific usability aspects of such applications.

Usability evaluation is a central process in developing usable, hence useful, hence high quality systems with which humans can interact. With the advent of mobile devices and apps, innovative usability evaluation methods have been proposed in either general (Yáñez et al., 2014; Quiñones et al., 2018; Rusu et al., 2011) and context-specific forms (Rusu et al., 2011; Yáñez et al., 2014; Gumussoy, 2016; Kuparinen et al., 2013; Mosqueira-Rey et al., 2018). The importance of taking into account context-specific characteristics when performing a usability evaluation is highlighted by the latter.

Therefore, this project proposed a usability evaluation methodology applicable to mobile ticketing applications in public transport with a real case application on *Anda*, Porto public transport system's recently launched solution, developed based on a selection of existing usability evaluation approaches, including general/classical and other field-specific literature approaches, that is to say, related to public transport mobile apps, and consisting of creation of context-specific list of heuristics and a checklist, real case application of a Heuristic Evaluation (HE) and Usability tests on *Anda* and, as a result, validation of the created heuristics' checklist and an extensive list of recommendations for the app, with mock-ups.

In the Metropolitan Area of Porto, Portugal, the complementary group of companies Intermodal Transports of Porto (TIP) and the Faculty of Engineering of University of Porto (FEUP) jointly developed a mobile application, *Anda*, that allow users to ride buses, light rail and heavy-rail trains in the extensive public transport network of Porto without anything but their mobile devices (Transportes Intermodais do Porto, 2018).

Besides the complete dematerialization of the public transport tickets, another innovation was the post-paid billing system that optimizes the customer's monthly tariff. That is, based on customer's usage, invoices may come in the form of a monthly pass or individual tickets, whichever is the most economical for customers (Transportes Intermodais do Porto, 2018).

In the specific case of Porto, the technologies required for the app to work are Near-field communication (NFC) plus Bluetooth and Global Positioning System (GPS), but other solutions for different metro areas have been proposed by researchers or are already being

implemented (Campos Ferreira et al., 2014b; Rodrigues et al. 2014; Campos Ferreira et al., 2015).

Regardless of the technologies employed in the mobile ticketing solutions, having usability consistency and harmony is essential for a system's acceptance. However, there have not been devised specific usability evaluation methods for public transport mobile ticketing solutions yet, due to being a technology newly launched in this peculiar context. Hence, this project's goal was to address this need by developing context-specific usability evaluation methodology to allow faster usability evaluations in upcoming systems related to the same field.

1.1 Research Objectives

1.1.1 General objective

Construct and validate a context-specific usability evaluation methodology that will produce artifacts applicable for public transport mobile ticketing solutions.

1.1.2 Specific objectives

- Formulate a list of Heuristics and a checklist for public transport mobile ticketing solutions;
- Perform a Heuristic Evaluation (HE) of a public transport mobile ticketing solution, *Anda*, with the checklist created;
- Perform Usability tests on the same solution;
- Upgrade the formulated Heuristics checklist, based on analysis and comparison of HE and Usability tests results; and
- Make recommendations for usability improvements in *Anda*.

1.2 Report outline

The remainder of this dissertation is comprised by the following topics:

- Chapter 2 – Literature Review: Presents the most relevant findings in the domains of public transport and mobile applications usability evaluation, development of context-specific usability evaluation methods. Also, it collaborates to justifying the relevance of this dissertation.
- Chapter 3 – Problem characterization: Collaborates to delimit the research context and explains in detail the current prospect of public transport mobile ticketing solutions around the world and recent developments in Porto, where a real case application takes place in the course of this dissertation.
- Chapter 4 – Methodology: Describes the stages from development of heuristics, application of HE and Usability tests on *Anda*, analysis of results, formulation of recommendations for the app, adjustments of heuristics to conclusions.
- Chapter 5 – Heuristic Evaluation: Describes in detail the process of formulating a list of heuristics and a checklist and of applying them in a real case HE. Also, presents the results of the HE.
- Chapter 6 – Usability test: Describes in detail the process of elaborating Usability test form and setting, and of performing real case Usability testing. Also, presents the results of the Usability tests.

- Chapter 7 – Evaluation and Discussion: Presents the interpretation of the research findings and the resulting recommendations for *Anda*, with illustrating mock-ups, and argues adjustments in the heuristics' checklist so that it gets more robust.
- Chapter 8 – Conclusion

2 Literature Review

2.1 Usability

The International Organization for Standardization (ISO, 2018) defines usability as the "extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use." According to Nielsen's (1993) classical definition, usability regards all features and prospects of a system which can be interacted and it is habitually identified by five attributes: learnability of the system, efficiency of use, easiness to remember (memorability), ability to recover from errors and subjective satisfaction.

According to Geisen and Bergstrom (2017), the concept of usability arose from the discipline of Human Factors and has been around for centuries. With the rise of personal computers in the 1980s, the terms "usability engineering" and "usability" became more prominent due to the importance of conceiving more intuitive PCs.

Marcus (2005, p. 17) states, as reason to put effort and resources in usability, that it "increases customer satisfaction and productivity, leads to customer trust and loyalty, and contributes to tangible cost savings and profitability."

Besides that, in the internet age, usability is a condition for survival. If users find it hard to understand how to use a system (e.g. a mobile application or a website), they simply do not use it, there are plenty of other options available for them to try. The user will not persist in a system when facing difficulties unless they really must do so, such as in the case of employees and company's intranet (Nielsen, 2012).

2.2 Usability evaluation techniques

After clarifying the abstract concept of "usability", it is necessary to methodically approach it and define forms of precisely measuring and evaluating it in order to improve products and users better understand them.

When software started reaching a larger audience in the early 1980s, usability evaluation techniques became more popular and, since then, many types of them have emerged (Dumas and Fox, 2008). Yáñez et al. (2014) provided a wide and yet non-exhaustive classification of such techniques, as shown in Figure 1.

Over real systems or prototypes, as is the case of public transport mobile ticketing solutions, evaluations conducted by experts or involving users are preferred. Predictive evaluations are frequently employed with an academic focus on under development (Yáñez et al., 2014).

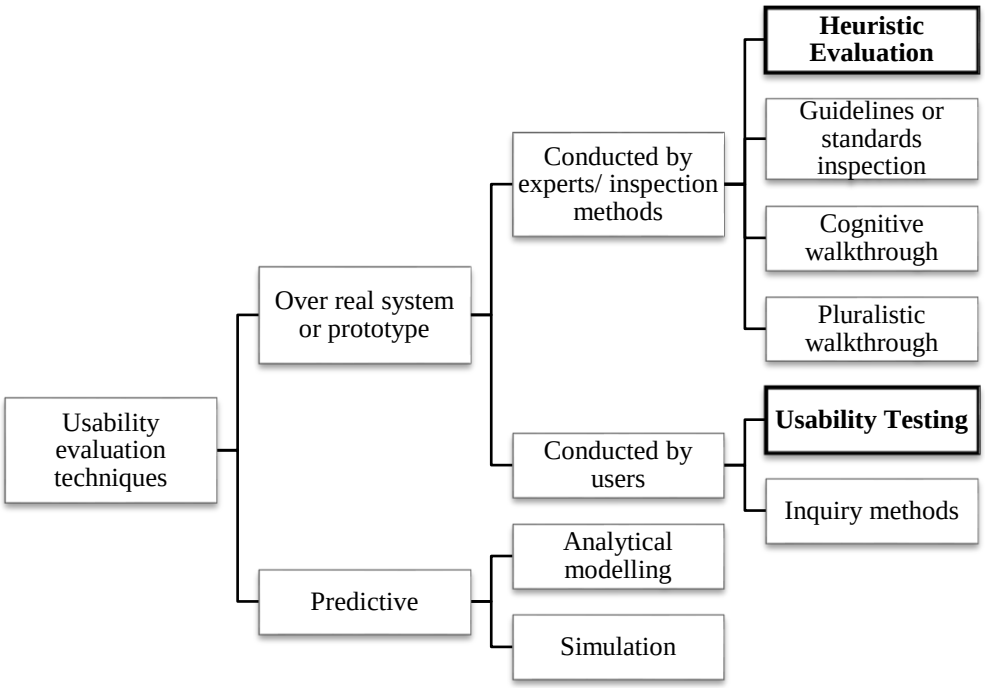

Figure 1- Classification of Usability Evaluation techniques (Adapted from Yáñez et al., 2014)

2.2.1 Heuristic Evaluation

Heuristic Evaluation (HE), sometimes called Expert Evaluation, is an evaluation performed by experts using a heuristic checklist (Rosenzweig, 2015). Heuristics are predetermined standard principles, often composed of broad rules of thumb (Gumussoy, 2016). A checklist can be designed to aid experts in identifying usability problems, but they shall be also encouraged to give further insights beyond the checklist (Khajouei et al., 2018).

Experts are called like that to differentiate them from regular users, and although they are required to have previous knowledge on usability, they do not necessarily have to be usability experts (Nielsen, 1994; Yáñez et al., 2014).

HE method's main goal is to identify problems associated with the design of user interfaces and its main benefits are being a fast and inexpensive technique that yields meaningful results (Tan et al., 2009; González et al., 2009).

2.2.2 Usability tests

Usability tests are a form of evaluation in which users are asked to interact with a prototype and give feedback about their understanding of it and easiness to use. The goal is to collect data empirically to make the prototype match the user's mental model (Rosenzweig, 2015). As a result, Usability tests can benefit both users and companies greatly, by making products easier to use and, hence, improving profitability (Rubin and Chisnell, 2008).

According to Rubin and Chisnell (2008), it is fundamental to plan beforehand to develop a Usability test. The key elements include, but are not limited to: a concrete purpose and problem statement; identification of a representative sample of users; selection of test environment; clear definition of how test sessions will be conducted; collection of data; and report of findings and recommendations.

2.2.3 Development of field-specific usability heuristics and checklist

Usability researchers and practitioners have long criticized traditional heuristics because they might not evaluate specificities of particular types of systems and may be too generic or broad. Therefore, many authors have developed field-specific sets of usability heuristics and checklists in order to perform such evaluations more efficiently and achieve more valuable results (Quiñones and Rusu, 2017; Mosqueira-Rey et al., 2018).

According to Quiñones and Rusu (2017), no consistent methodology has been employed through the various articles regarding development of field-specific usability heuristics. Although some models have been used more than others – for instance, Rusu et al.'s (2011) and Van Greunen et al.'s (2011) –, most researchers use solely their vast field-related experience and usability knowledge to develop new sets of heuristics and checklists.

Kuparinen et al. (2013) have proposed a methodology for establishing new specific usability heuristics by using traditional heuristics and adapting them a particular field. Yáñez et al. (2014) go further by researching comprehensively traditional and field-specific heuristic checklists and best practice manuals, then adapting and merging subheuristics to homogenize the redaction and format, so that the final heuristic checklist covers the application thoroughly.

Hermawati and Lawson (2016) agree to that by indicating that traditional heuristics, such as Nielsen's, can be applied to evaluate various types of user interfaces if they are adjusted accordingly. That is, Nielsen's heuristics may address a large portion of usability problems in an application, but if they are not adjusted to the application's field, specific usability problems might be completely missed.

2.3 Public transport mobile ticketing solutions

Mobile solutions are software applications, or "apps", built to run on smartphones, tablets and other mobile devices. They have become fundamental for people in the past decade because of the fast technological advances experienced nowadays. In the transport sector, "Apps" are used for many functions, including route planning, ridesharing, travel information and others; but not always for general public benefit, e.g. applications that detect radars and inform the driver to slow down when crossing the location (Siuhi and Mwakalonge, 2016).

Public transport mobile payment is one of the applications of mobile solutions. According to Dahlberg et al. (2008, p.165), mobile payments can be defined as "payments for goods, services, and bills with a mobile device by taking advantage of wireless and other communication technologies". Therefore, public transport tickets are among such services and bills. Slade et al. (2013) explains that new m-payments systems usually fail to achieve sufficient consumer adoption in order to last long enough because, among other reasons, they are not easy to use.

By any means, public transport mobile ticketing solutions are an innovative type of service offering provided by Public Transport Operators (PTOs) relying solely on customers' mobile devices to purchase and validate tickets. With this solution, the investment costs boil down to software acquisition and maintenance and database management (Campos Ferreira et al., 2014a).

Fontes et al. (2017) state that although this new technology cannot make traditional ticketing systems disappear by completely replacing them, it is able to boost the global efficiency of transport networks.

Users benefit from more convenience in purchasing and validating tickets, not needing to carry cash around and saving time by avoiding queues. PTOs benefit from less operational and maintenance costs. However, users can feel disquieted about privacy, reliability and interaction issues of such solution (Fontes et al., 2017; Campos Ferreira et al., 2014a).

Thus, usability concerns are intrinsically related to the success of public transport mobile ticketing solutions, either to improve user interaction and to help the mobile payment/ticketing system to acquire critical mass of consumers so that it becomes relevant and longevous. Cheng (2017) is emphatic that a good user experience in public transport mobile ticketing solution increases appeal and initial user base; a potential usage funnel is presented in Figure 2 with three major Usability measures (Effectiveness, Efficiency and Satisfaction) as determinant to the retained user base.

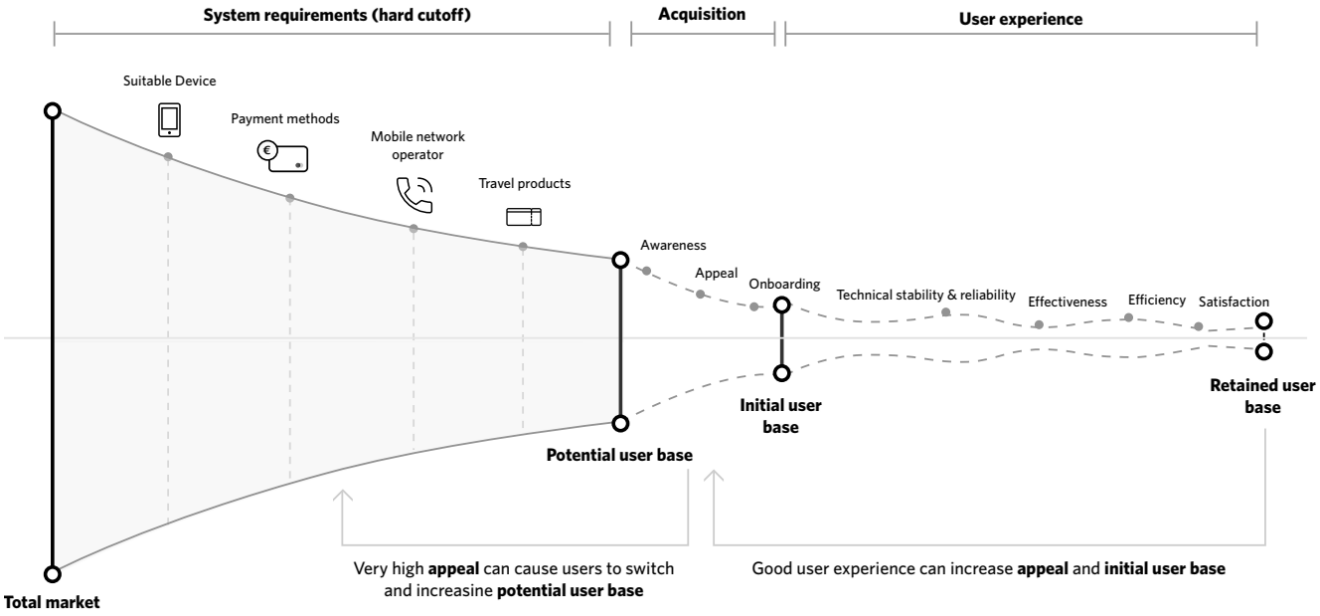

Figure 2- Potential usage funnel (Cheng, 2017)

2.4 Conclusions and Research contributions

Public transport mobile ticketing solutions are a new form of technology based on smartphones that have become recently available in some cities, such as Bordeaux, France (Fontes et al., 2017). The odds for this innovation to succeed will increase if abovementioned usability concerns are taken care of.

This argument can be validated by Laukkanen and Lauronen (2005), who emphasized that usability problems are accountable for low adoption of various payment systems, and by Mallat et al. (2008), who identified that ease of use and use context, among other nine aspects, influence new technology adoption, being ease of use and perceived usefulness determinants to use intention, which, in its turn, predicts actual use of a system.

Because of its freshness, this kind of solution does not hold a field-specific instrument to address usability issues during development phase yet. This research contributes in developing such instrument, namely a Heuristics checklist. This tool provides a fast, inexpensive and reliable method for evaluating usability in mobile applications.

In order to make the Heuristics checklist more robust and dependable, it was applied to *Anda*, the mobile ticketing solution developed for Porto public transport network. Then, its results were compared with the outcomes of in-context usability tests that were performed to evaluate the same application.

For public transport related products and systems, the value of in-context/ field usability tests in comparison with out-of-context/ laboratory tests is that the first are more realistic and take into account relevant dynamic factors (Hussain et al., 2017; Hörold et al., 2014). Nonetheless, Kaikkonen et al.'s (2005) findings are antagonistic to this by stating that in-context usability tests may not necessarily be the best option; mostly due to being lengthier than a lab test.

After analyzing both evaluations, the Heuristics checklist was validated and *Anda* benefitted from two usability studies. Recommendations for improving usability aspects of the Portuguese application were provided and guidelines for an in-context usability test of a public transport mobile ticketing solution were created. Even though the in-context usability test guidelines were specifically designed for *Anda* and cannot be generalized like a Heuristics checklist, they can be used as an influence or source to future usability studies of *Anda* or similar applications.

3 Problem Characterization

The natural inclination for a more comfortable life even in routine tasks has led to a more digital and urban life. Tasks like ordering food, buying a coffee or acquiring a subway ticket are done through smartphones. Holding on to this, many public transport mobile ticket solutions have arisen or are under development but not following field-specific standardized usability guidelines like the proposed Heuristics.

A new technology can face many difficulties when it is launched for a number of reasons, as mentioned in topics 1.2, 2.3 and 2.4. And, although there are studies pointing to the importance of developing field-specific usability heuristics (Yáñez et al., 2014; Quiñones & Rusu, 2017; Rusu et al., 2011; Gumussoy, 2016; Kuparinen et al., 2013; Mosqueira-Rey et al., 2018; Hoehle & Venkatesh, 2015), especially for new technologies, there has not been found any well-known works concerning the subject in public transport mobile ticketing solutions.

3.1 Types of mobile ticketing solutions

There are several types of mobile ticketing solutions are already in place and they rely in different kinds of technology as they have to be adapted to diversified ticketing systems in cities' public transport networks. Gonzalez Sanchez (2016) identified some of the most common mobile ticketing solutions by looking up twenty different public transport contexts. Campos Ferreira et al. (2014a) described other solutions before devising a new one to a particular city, Porto. To these were adjoined other solutions experienced by the author and the result is presented in Figure 3.

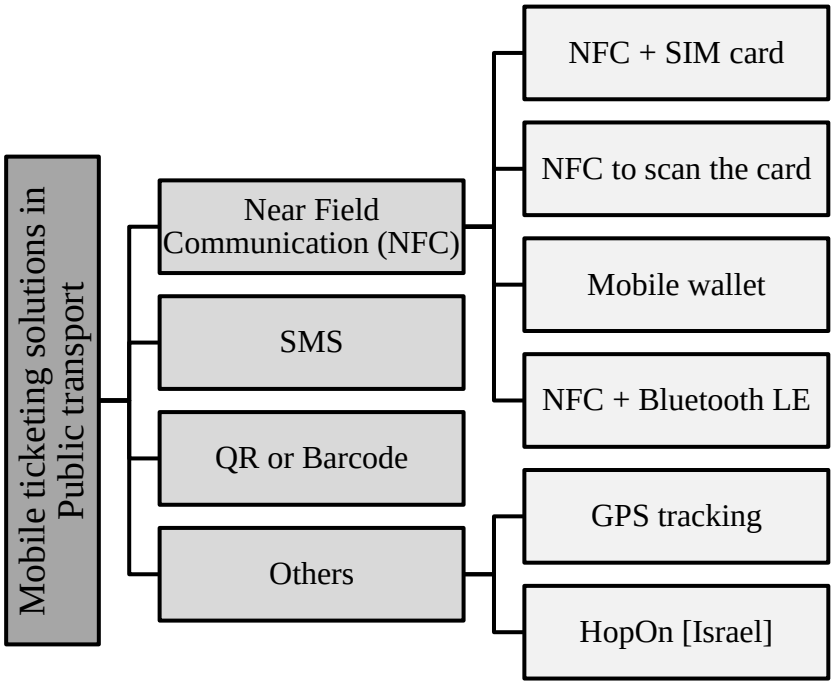

Figure 3- Public transport mobile ticketing solutions by technology used (Adapted from Gonzalez Sanchez, 2016)

Near Field Communication is a wireless technology that allows devices in very close proximity to establish connection almost instantaneously, without any setting up process, to exchange data through radio waves. According to Gonzalez Sanchez (2016), NFC is the most

used technology for mobile payments in physical stores and other services, but there have been obstacles before reaching success in public transport systems. These challenges are strongly related to the lack of proper infrastructure and complexity of multiple stakeholders and standards.

NFC + SIM card is a model devised to overcome the lack of NFC readers in poles and gates in some public transport networks because many of the systems were developed prior to the standardization of NFC. In this model, the SIM card works as an emulator and bridges the NFC to the technology built in the poles and gates. This model is currently used in Hong Kong (Gonzalez Sanchez, 2016).

NFC to scan the card does not dismiss the use of a physical smartcard; users can scan the card and through a mobile application buy tickets. This model is also used in Hong Kong and the Netherlands (Gonzalez Sanchez, 2016).

Mobile wallet is the most used model in public transport that requires NFC. Users store credit or debit card information in mobile applications like Apple pay or Android pay and use their smartphones to pay tickets instead of an actual card (Gonzalez Sanchez, 2016).

NFC + Bluetooth LE is a model created for networks with check-in be out ticketing system – that is to say, systems in which users check in by bringing their mobile device to a pole which registers the point of origin and whenever the user gets off the mean of transportation, Bluetooth connection will be out of range and dismissed. This model is used in Porto.

SMS is one of the original mobile ticketing solutions. In this model, users send text messages to Public Transport Operators (PTOs) in order to buy tickets. It has limitations such as difficulties in payment and lack of encryption method (Campos Ferreira et al. 2014a). This model is in place in Prague and Antwerp.

QR and barcode are the most popular technologies by PTOs due to the easiness to implement and reduced costs. Users buy tickets through an app and it creates a QR or barcode that can be used for checking-in, inspections and checking out, depending on the network design (Gonzalez Sanchez, 2016).

Other models deemed as less common were also identified by Gonzalez Sanchez (2016), like *GPS tracking* available in Germany, in which users are requested to check in and out through an app and journey is followed via GPS, and *HopOn* from an Israeli start-up company, the app allows to pay through it and uses ultrasonic sound waves for validation with the phone.

3.2 Public transport networks with mobile ticketing solutions in place

In a non-exhaustive research, public transport mobile ticketing solutions were discovered to be already in place or in development stage in more than a 100 cities and metropolitan areas across the world as presented in Figure 4 and described in Table 1.

Even though this list is only partial and there surely are more cities and metro areas with mobile ticketing solutions in place or under development for their public transport systems, the first conclusion from such a vast number of available and planned solutions is how promising the field looks now. For instance, Garfield (2018) states that the taxi cab, food delivery and transportation network company, Uber, wants to take advantage of this prospect and thrive by joining forces with the technology company that has developed more than thirty mobile ticketing services for PTOs, Masabi, and integrating its services on Uber’s app.

Another conclusion comes from the clear concentration of mobile ticketing solutions in the most developed regions of the world. This is symptomatic of a wider technology innovation problem that perpetuates the status quo of less developed nations as laggards and commodity-dependant countries with poorly diversified economies.

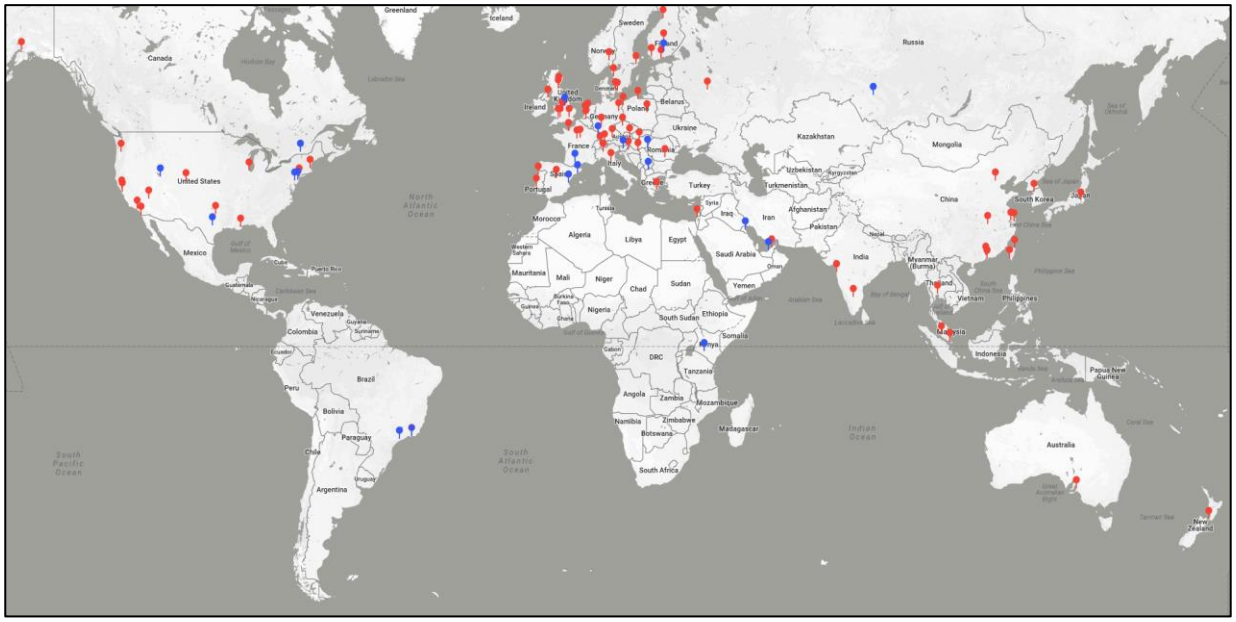

Figure 4- Partial map of cities and metro areas with public transport mobile ticketing solutions: Red pins – Solutions already in place; Blue pins – Under development

This study focuses on the creation of Usability Heuristics for fast and secure evaluation of mobile ticketing solutions for public transport. Still, a Usability study must be applicable in the real world and cannot be completely dissociated of a context of use; and there must be a way to validate such Heuristics. Therefore, a Usability tests were performed at *Anda*, Porto's public transport mobile ticketing solution, and to create a frame for interpreting the results of the study, a succinct introduction to the application is necessary.

Table 1- Partial list of cities and metro areas with public transport mobile ticketing solutions

Continent	Working solutions	Solutions under development
Africa		Nairobi
Asia	Bangalore, Bangkok, Beijing, Dubai, Guangdong, Hong Kong, Kaohsiung, Kuala Lumpur, Mumbai, Seoul, Shanghai, Shenzhen, Singapore, Suzhou, Taipei, Tel Aviv, Tokyo, Wuhan	Abu Dhabi, Kuwait City
Europe	Amsterdam, Antwerp, Arad, Athens, Belfast, Berlin, Birmingham, Bristol, Bucharest, Budapest, Caen, Cardiff, Copenhagen, Dundee, Edinburgh, Florence, Frankfurt, Gdańsk, Gothenburg, Helsinki, Jyväskylä, Liechtenstein, Lisbon, London, Madrid, Malmö, Montargis, Moscow, Munich, Orléans, Osijek, Oulu, Prague, Porto, Rotterdam, Stockholm, Switzerland (most cities), Szczecin, The Hague,	Arad, Barcelona, Lahti, Ljubljana, Novosibirsk, Sheffield, Skopje, Strasbourg, Toulouse, Valencia

	Turku, Vienna, Walsall, Warsaw, Wolverhampton, Zagreb	
North America	Anchorage, Boston, Chicago, Dallas, Denver, Las Vegas, Los Angeles, New York, New Orleans, San Diego, San Francisco, Sonoma and Marin	Austin, Montréal, New Jersey, Philadelphia, Salt Lake City
Oceania	Adelaide, Wellington	
South America		São Paulo, Rio de Janeiro

3.3 The *Andante* network in Porto

Metropolitan Area of Porto (MAP) has a population of approximately 1.7 million people and it is composed of 17 municipalities in an area of 2,040 square kilometers located in the northern coast of Portugal (AMP, 2018).

In MAP, the public transport system is composed by three subsystems: buses, light rail and suburban trains. In 2002, when light rail began services, the *Andante*, a multimodal public transport ticketing system, was developed so that these subsystems complemented each other. The complementary grouping of companies Intermodal Transports of Porto (TIP) is behind *Andante* and its purpose is integrating multimodal transport in MAP. TIP is participated by *Metro do Porto* (light rail), *Sociedade de Transportes Colectivos do Porto* (buses) and *Comboios de Portugal* (suburban trains).

The *Andante* card uses a contactless technology based in radio frequency, with which it is only necessary to approach validating machines in light rail or suburban train stations and buses, as presented in Figures 5 and 6. Users can purchase a monthly pass card or an occasional card, able to store multiple tickets for future travels. Such cards are sold in *Andante* stores, vending machines, adherent PTOs service stations, *Pagaqui* agents and a few resellers.

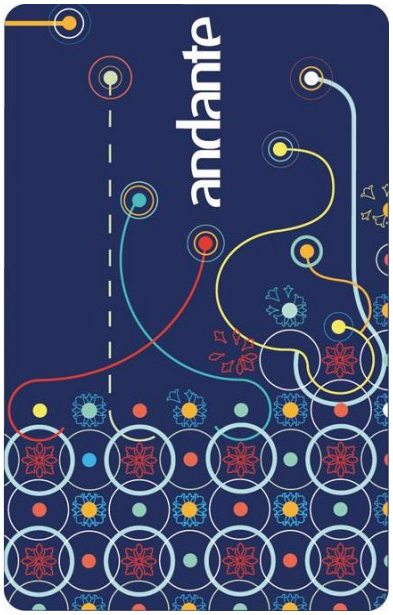

Figure 5 - Andante card

Figure 6 - A validation with Andante card

Only eleven out of thirty PTOs that work in MAP are adherents to the network, so 83% of bus lines in the region cannot be accessed using the contactless cards, especially the ones far from city centre (Transportes Intermodais do Porto, 2016). In Figure 7, the effective area of *Andante* is depicted.

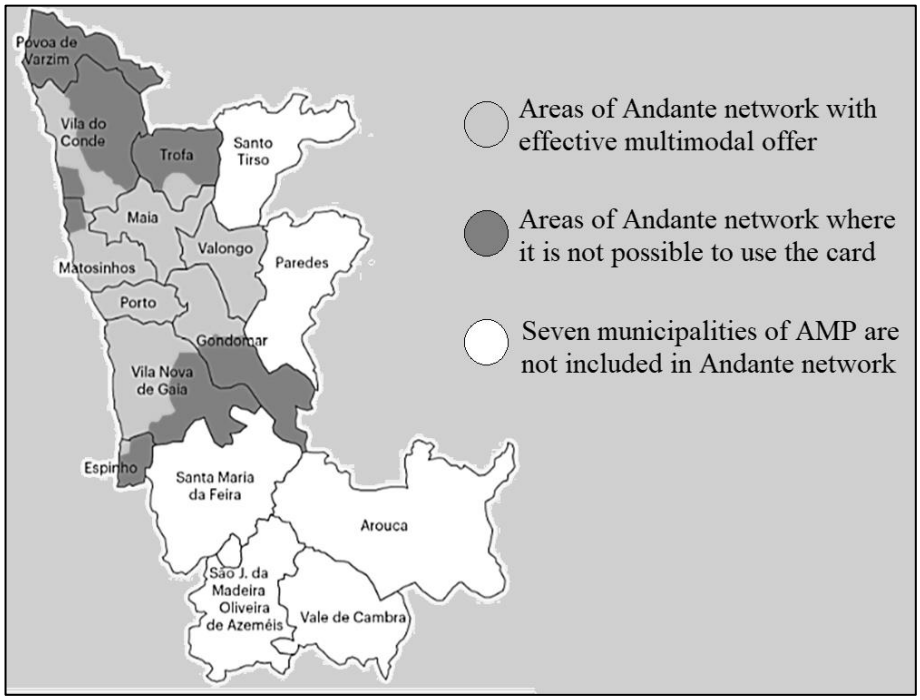

Figure 7 - Effective area of Andante network (Adapted from Edição Público Porto, 2016)

The fare system of *Andante* is quite unique. It is not concentric and it is divided in zones defined based on travel patterns and local geography, then fairer, but much more complex for users (Domingues, 2004). The fare depends on the number of zones that users need to cross during their journey, the farther a user goes from their original point, the more expensive. Travel tickets range from Z2 to Z12 and time allowance to use them increase according to the number of zones included, as depicted in Table 2.

Table 2 – Description of Andante travel tickets

Travel tickets	Time allowance	Price
Z2	1h00m	€ 1.20
Z3	1h00m	€ 1.60
Z4	1h15m	€ 2.00
Z5	1h30m	€ 2.40
Z6	1h45m	€ 2.80
Z7	2h00m	€ 3.20
Z8	2h15m	€ 3.60
Z9	2h30m	€ 4.00
Z10	2h45m	€ 4.40
Z11	3h00m	€ 4.80
Z12	3h15m	€ 5.20

Andante's zoning system is shown in Figure 8 with an example of what kind of travel ticket is needed to travel departing from the Faculty of Engineering of University of Porto, in zone C6. The distinction between Central (C1-C16), Northern (N1-N17) and Southern (S1-S13) zones does not influence the fare system. Porto's city centre is defined as zone C1.

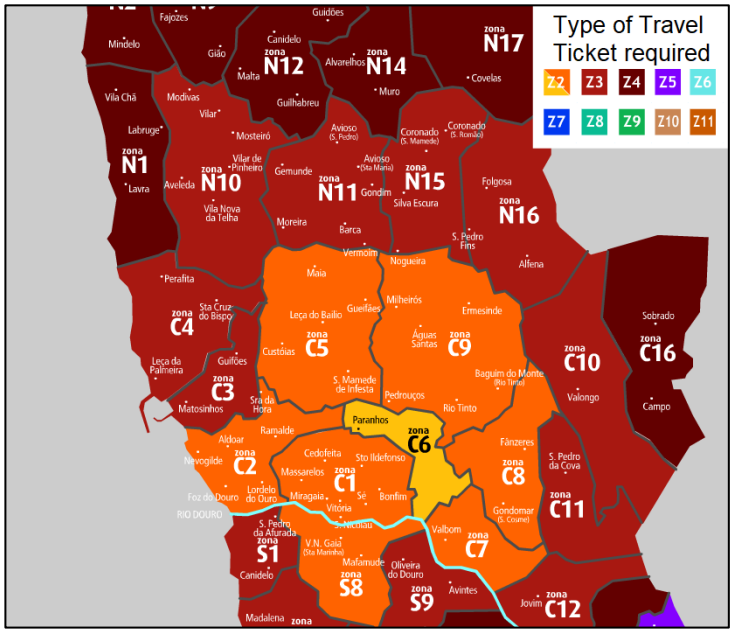

Figure 8 - Simulation of a travel with Andante departing from zone C6

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 8, users are lead to believe that if they want to go from some point in C6 to N10, they need a Z3 travel ticket in whatever situation. However, if a user chooses to use light rail 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 heading to N10, and from C1 to N10 the number of zones is larger.

3.4 *Anda* app

As a form of facilitating the usage of *Andante* network, the mobile application *Anda* was under development by TIP in collaboration with Faculty of Engineering of University of Porto since 2016 and it was launched in the end of June of 2018. Using this app, it is not necessary to stand in queues or to carry cash around to purchase tickets; also the physical *Andante* card is rendered dispensable. All actions required to travel in MAP public transport can be done with a smartphone, from ticket payments to validation, as presented in Figure 9. And that is not all.

Anda has a postpaid billing system, so users can travel as they will and they are charged only by the beginning of the next month. This feature enables the app to calculate the optimal fare for users based on their travels, that is to say, in some months it might make sense to buy a monthly pass, but in some other months, especially during holidays or vacation, users may travel less and occasional travel tickets could be the most economical option, then *Anda* will charge the most cost-effective alternative for users.

Figure 9 - A validation with Anda app

The zoning system complexity also fades away as the mobile ticketing solution, based on user's point of origin and final destination, can identify the type of travel ticket necessary without any input. The following Figures 10, 11, 12 illustrate *Anda* functioning in different smartphones:

Figure 12 - Anda Home screen

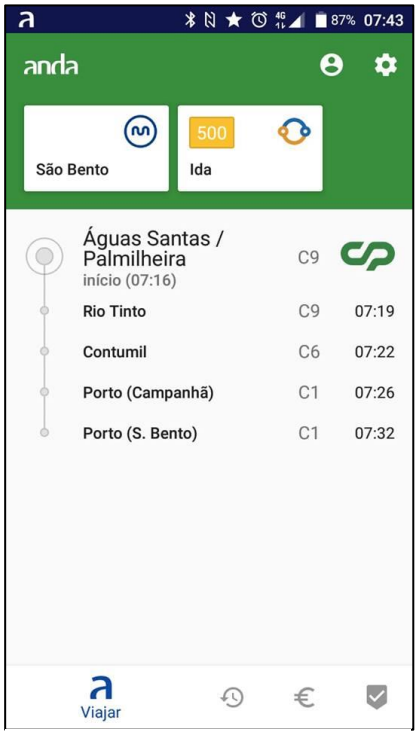

Figure 10 - Anda Travel screen

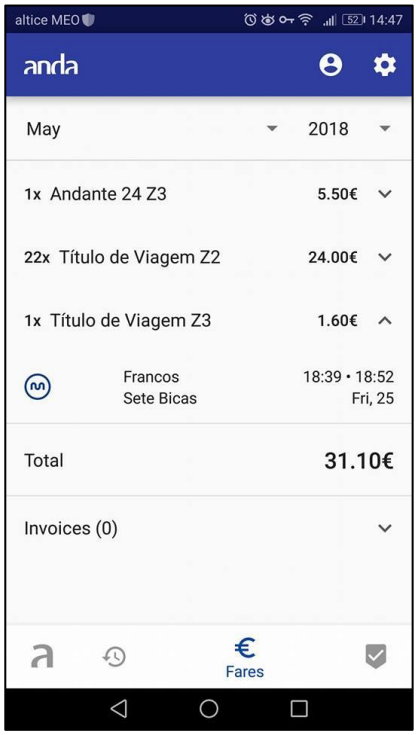

Figure 11- Anda Fares screen

In order to use this mobile ticketing solution, it is necessary to have a smartphone equipped with NFC – to validate before starting a travel – and Android operating system, with version 5.0 or higher, because it was not possible to develop the same technology for iOS yet.

Because *Andante* network is a check-in be out ticketing system, *Anda* requires access to Bluetooth as well, so that it is possible to identify where the user finished the journey, as explained in section 3.1 of this work.

4 Methodology

The elaboration of this work took place through the stages shown in Figure 13.

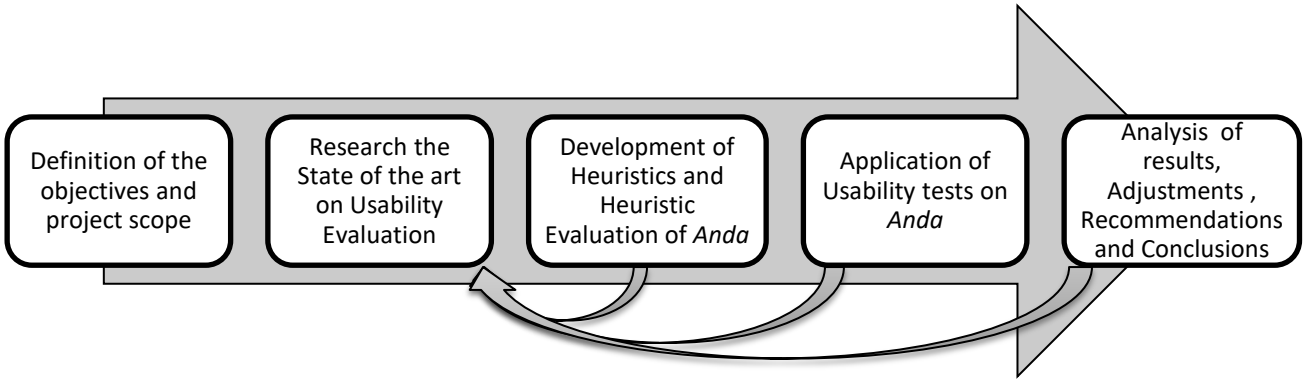

Figure 13- Stages of the work

In the first stage of this work, the definition of the research objectives and project scope was based on the state of the art on Usability topics related to public transport mobile ticketing apps and discussions carried out with the supervisors of this dissertation, other scholars, public transport professionals and app developers about *Anda*.

The second stage was investigative; it consisted of researching the state of the art on Usability evaluation, focusing on publications related to public transport apps, Mobile payments or ticketing, public transport mobile ticketing apps, How to develop Heuristics and checklist, and How to perform Usability tests.

After that, the third stage was to develop general Heuristics and a Checklist for public transport mobile ticketing apps and, from this, perform the Heuristic Evaluation of Porto's public transport mobile ticketing app, *Anda*, and analyze results.

The fourth stage was to create guidelines for and carry out a Usability test on *Anda*. Results were analyzed subsequently.

Finally, the fifth stage was to analyze and compare the results of the Heuristic Evaluation and Usability tests together, validate or not the Heuristics developed, make possible adjustments to them, make recommendations for usability improvements on *Anda* and, finally, draw conclusions.

Sometimes, during third, fourth and fifth stages it was necessary to go back immersing again in journals and books and do additional research on the topics.

4.1 Development of Heuristics and Heuristic Evaluation of *Anda*

The third stage is described in Figure 14. It involved, firstly, defining a new list of Heuristics and a Checklist to be applicable for public transport mobile ticketing apps.

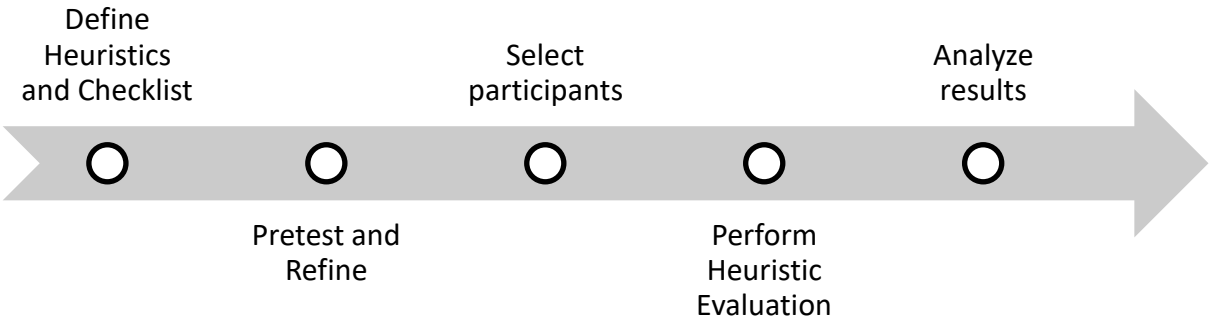

Figure 14 - Steps to the Heuristics

Secondly, the Heuristics were pre-tested by the dissertation's supervising professors and refined until it was appropriate. Afterwards, three usability experts and the author were asked to answer the checklist having in mind the *Anda* app. The experts were selected because of their experience with usability. Then, the Heuristic Evaluation of the aforementioned application was performed and the results were analyzed.

4.2 Application of Usability tests on *Anda*

The fourth stage is described in Figure 15. The Usability test guidelines were based on previous usability tests performed on *Anda* and the publications of Rubin & Chisnell (2008), Dumas & Fox (2008), Lewis (2006) and Prescott & Crichton (1999). The guidelines are available in Appendix C and comprise questions regarding the user's experience with Android Operating System, *Andante* network and *Anda* app; questions about user's most frequent and likely actions within *Anda* application; and a final short open interview.

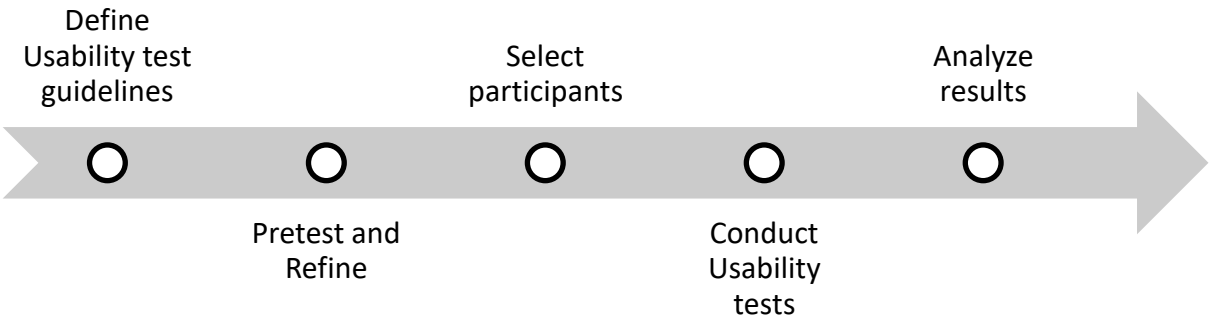

Figure 15 - Steps to the Usability tests

Later on, the test guidelines were preliminarily assessed by the supervising professors and then refined by the author as recommended.

The criteria for selecting participants were:

- Having a smartphone with NFC technology and Android Operating System, version 5.0 or higher;
- Residing in the Metropolitan Area of Porto;
- Being a user of public transport.

According to Dumas and Fox (2008), between 5 and 8 users suffice for a test to have comprehensive and meaningful results. Hence, 8 users were selected for testing, being 4 of them first-time users of *Anda*. Tests were conducted in some of Porto's light rail stations and their results went through a thorough analysis.

4.3 Analysis of results and Conclusions

In the fifth stage, described in Figure 16, the results of the Heuristic Evaluation and Usability tests were compared and analyzed together. Comprehensive evaluation and discussion of them were made.

Since results of HE were more efficient overall than those of Usability tests, Heuristics went through pointed adjustments in order to increase its scope and were validated for general application in public transport mobile ticketing solutions.

Based on results of both usability evaluation methods, far-reaching recommendations for *Anda* were made, with some mock-ups developed to better illustrate some of them.

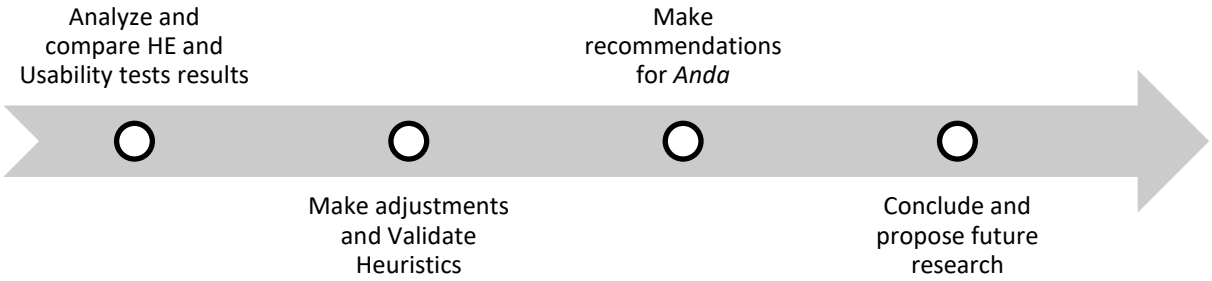

Figure 16 - Steps to Analysis and Conclusion

Finally, based on findings of this research, a conclusion was drawn and future research on the topic was proposed.

5 Heuristic Evaluation

5.1 Development of list of Heuristics and Checklist

Since science is about building on what others have already built and collaborating with it, the Heuristics developed was adapted from Nielsen and Mack (1994), Pierotti (1995), Kuparinen et al. (2013) and Rusu et al. (2011). The complete list and definition of Heuristics developed is in the fourth column ("Final") in Table 3, being the other three columns the above-mentioned sources of inspiration.

The reason for choosing Nielsen and Pierotti's papers as main sources for the Heuristics' definition was that they were considered relevant and influential papers to the Usability research field, true all-time classics, and they were frequently referenced by other researchers, as in works of Yáñez et al. (2014), Quiñones & Rusu (2017), Rusu et al. (2011), Gumussoy, (2016), Kuparinen et al. (2013) and Mosqueira-Rey et al. (2018).

Kuparinen et al.'s paper was used because it contained a new Heuristics developed for mobile map applications. Rusu et al.'s paper contained a number of Heuristics developed for specific purposes and, besides that, Rusu is also well-known for developing new Usability paradigms, as in Inostroza et al. (2012), Quiñones & Rusu (2017) and Quiñones et al. (2018).

Table 3 - List of Heuristics compared

Nielsen and Mack (1994) & Pierotti (1995)	Kuparinen et al. (2013)	Rusu et al. (2011)	Final
1. Visibility of system status The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.	**1. Visibility of the contextual map functions** The map application should always keep the user informed about what is going on, through appropriate feedback within a reasonable time. The map functions should be visible.	**4. Visibility of the system status** Feedback on system status should be continuously provided.	**1. Visibility of system status*** The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.
2. Match between system and the real world The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.	**2. Match between the system and the physical surroundings of the user** The map application should show clear indication of the user's current location on the map and of the possible target location. It is essential that the map compares in an understandable way with the physical surroundings of the user. The map should be up-to-date.	**1. Match between the system and the real world** iTV should use words, phrases and concepts familiar to the user; the sequence of activities should follow user's mental processes; information should be presented in a simple, natural and logical order; metaphors should be easy to understand; important controls should be represented on screen; there should be an intuitive mapping between them and the real controls.	**2. Match between system and the real world*‡** The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order. Metaphors should be easy to understand.

3. User control and freedom Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.	**3. User control over map functions and locations** Allow the user to take control over map application when interruptions (from the mobile device: phone call, message, other applications' notifications, from the concrete surroundings: traffic, weather, traffic lights) happen.	**11. User control and freedom** iTV should provide "undo" (or "cancel") and "redo" options; exits should be clearly marked (when users find themselves somewhere unexpected); facilities to return to the top level should be provided, at all stages.	**3. User control and freedom***‡ The system should have (a) clearly marked exit(s) to leave an unwanted state and return to the previous or the top level. Support undo and redo.
4. Consistency and standards Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.	**4. Consistency and standards** Follow platform conventions. Use clear, intuitive, commonly known map symbols.	**3. Consistency and standards** iTV should use terminology, controls, graphics and menus consistent throughout the system; there should be a consistent look and feel for the system interface; iTV should be consistent with the related standard TV programs, and colors should be consistent between the two systems.	**4. Consistency and standards**† Follow platform conventions. Use clear, intuitive, commonly known mobile application symbols.
5. Error prevention Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.	**5. Error prevention** Even better than good error messages is a careful design, which prevents a problem from occurring in the first place. If errors still happen, make sure to offer the possibility to recover from them.	**12. Error prevention** iTV should offer a selection method provided (e.g. from a list) as an alternative to the direct entry of information; user confirmation should be required before carrying out a potentially "dangerous" action (e.g. deleting something).	**5. Error prevention***† Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action. If errors still happen, make sure to offer the possibility to recover from them.
6. Recognition rather than recall Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.	**6. Recognition rather than recall** Make sure that the main functions of the map application (e.g. search, route guidance, zooming, panning) are easily accessible. Use short menu paths for the main functions or keep the main functions visible at all times.	**9. Recognition rather than recall** iTV should allow for a wide range of user expertise; it should also appropriately guide novice users.	**6. Recognition rather than recall**†‡ Make sure that the main functions of the application are easily accessible and that their actions are intuitive. Use short menu paths for the main functions or keep the main functions visible at all times.

7. Flexibility and efficiency of use Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.	**7. Flexibility and efficiency of use** Offer flexible options for the main map functions. Allow the user to save locations to be used as shortcuts (e.g. home) and support POI information. Give easy access to additional information (metadata, links, user-generated content). Make sure the user interface is scalable for different screen sizes of mobile devices.	**10. Flexibility and efficiency of use** A Grid Computing application should prevent users from performing actions that could lead to errors, and should avoid confusions that could lead to mistakes.	**7. Flexibility and efficiency of use*†** The system should cater to both experienced and inexperienced users. Allow users to tailor frequent actions. Appropriately guide novice users. Make sure the user interface is scalable for different screen sizes of mobile devices.
8. Aesthetic and minimalist design Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.	**8. Balanced and simplistic visual design** Harmonious overall appearance should consist of clear contrast between visual elements, balanced layout and informative colors. Avoid visual clutter.	**2. Aesthetic and minimalist design** iTV should have simple, intuitive, easy to learn and pleasing design; the system should be free from irrelevant, unnecessary and distracting information; icons should be clear and buttons should be labeled; the use of graphic controls should be intuitive; the need for scroll should be minimized; navigation facilities should be present at the bottom of the screen.	**8. Aesthetic and minimalist design‡** The application should have simple, intuitive, easy to learn and pleasing design. The system should be free from irrelevant, unnecessary and distracting information. Graphic controls should be intuitive.
9. Help users recognize, diagnose, and recover from errors Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.	**9. Help users recognize, diagnose, and recover from errors** Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution. Indicate clearly the reasons if the searched locations are not found. Save the user's previous searches for fast repetition.	**13. Help users to recover from errors** Error messages should adequately describe problems; they should assist in diagnosis and suggest ways of recovery in a constructive way; error messages should be written in a nonderisory tone and refrain from attributing blame to the user.	**9. Help users recognize, diagnose, and recover from errors*‡** Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution. Error messages should be written in a nonderisory tone and refrain from attributing blame to the user.
10. Help and documentation Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any	**10. Help and documentation** Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Provide both: fast guidance focused	**14. Help and documentation** TV should offer clear, direct and simply help, expressed in user's idiom, free from jargon and buzzwords; help should be easy to search, understand and apply.	**10. Help and documentation‡** The application should offer clear, direct and simply help, expressed in user's idiom, free from jargon and buzzwords; help should be easy to

such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.	on the user's task and a more detailed guide with search functions.		search, understand and apply.
11. Skills The system should support, extend, supplement, or enhance the user's skills, background knowledge, and expertise ---- not replace them.			**11. Skills*** The system should support, supplement, extend, or enhance the user's skills, background knowledge, and expertise ---- not replace them.
12. Pleasurable and Respectful Interaction with the User The user's interactions with the system should enhance the quality of her or his work-life. The user should be treated with respect. The design should be aesthetically pleasing- with artistic as well as functional value.			**12. Pleasurable and Respectful Interaction with the User*** The interactions with the system should enhance the quality of the user's work-life. The user should be treated with respect. The design should be aesthetically pleasing- with artistic as well as functional value.
13. Privacy The system should help the user to protect personal or private information- belonging to the user or the his/her clients			**13. Privacy*** The system should help the user to protect personal or private information.

*Adapted from Nielsen and Mack (1994) and Pierotti (1995). †Adapted from Kuparinen et al. (2013). ‡Adapted from Rusu et al. (2011).

The Heuristics' checklist was developed mainly based on Yáñez et al.'s (2014) work, as it consists of a quite vast literature review on Heuristics checklists both for desktop and mobile devices. The other papers used also develop their own heuristics' checklists for their own purposes: banking apps, contributing mainly for payments and security, in Gumussoy (2016); and contributing with general checklists for mobile applications, in Mosqueira-Rey et al. (2018), Hoehle and Venkatesh (2015) and Monkman and Kushniruk (2013). The complete Heuristics' checklist is in Appendix B.

5.2 Setting

For the HE, four Usability experts, including this work's author, were asked to provide their feedback on *Anda* app answering the list of thirteen Heuristics and the Checklist of subheuristics (present in Appendix B), also commenting on each of them while using the mobile ticketing solution in context, that is, the experts replied to the checklist riding public

transport and using the app – not all questions were required to be performed in context though.

In the checklist, there were 156 Yes, No or Not Applicable questions elaborated based on previous checklists and usability manuals as explained in section 5.1. The questions were designed in a way that when answered with a "Yes" it meant that the app complied with the concerning subheuristic. When "No" was the answer, it meant that the application did not fulfill the precondition and the experts were invited to explain their answers and give opinions. A "No" answer was not always considered a negative evaluation if the expert did not believe that the attribute assessed by a subheuristic was not essential. "Not Applicable" answers were only given when experts deemed that a component did not exist in the application hence could not be evaluated.

The author of this work was the first among the Heuristic evaluators, so that the comments of the invited experts would not influence the evaluation. The average time for performing the HEs was 71 minutes. When all evaluators were done, a final table merging all answers was created and rows looked like the example in Table 4.

Table 4 - Example of Subheuristic in the checklist

1. Visibility of System Status		Yes	No	N/A
1.1	Is there some form of system feedback for every operator action?]	**3**	**1**	**0**

It was considered a Usability problem whenever two or more evaluators replied "No" to a subheuristic, except when evaluators expressed that, despite the negative answer, such aspect should not be a problem. Whenever there was only one "No", any number of "N/A" or critical opinions in spite of an all-positive answer, the Usability issue could be considered a problem depending on its relevance. In the end, the direct approach of the checklist did not mean that its analysis would be equally straightforward due to the complexity of Usability heuristics.

Payment function could not be tested properly as the HE occurred in a beta version of *Anda*, before official launching, so trips did not generate any kind of invoices.

5.3 Results of Heuristic Evaluation

In total, 41 Usability problems were identified after the HE. They were distributed per Heuristic as presented in the following Figure 17. More than half of the issues were found in only three Heuristics. Problems with Visibility of System Status were the most recurrent, with 9 out of 41. Problems with Privacy and Consistency & Standards were next, with 6 each. Besides that, 4 problems were found regarding Match between System and the Real World; 3 in User Control and Freedom; 3 in Help users recognize, diagnose, and recover from errors; and 9 in other Heuristics. No problems were discovered concerning Skills.

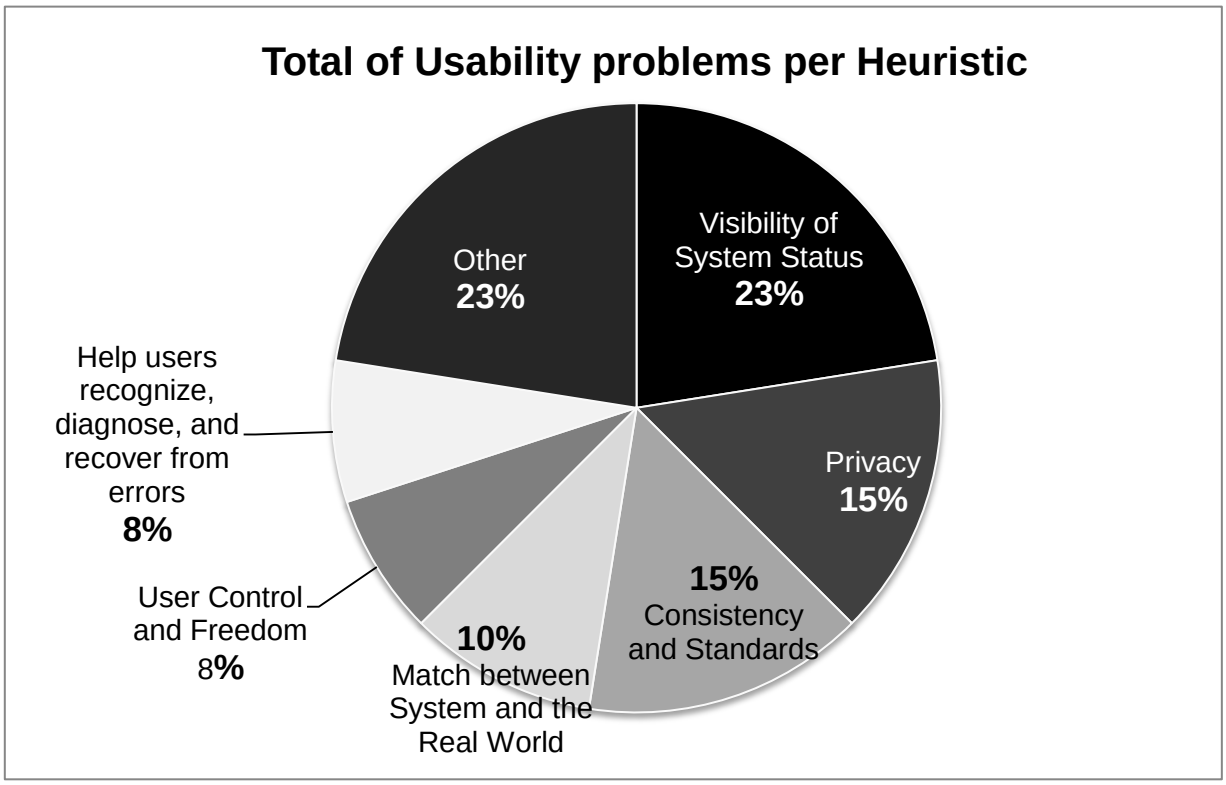

Figure 17 - Total of Usability problems per Heuristic, detected by HE

To facilitate analysis and help providing recommendations focusing on what matters the most, Usability problems were then divided in three categories depending on how much they affected the use of the application:

- Critical: Seriously decays usability – severe problems involving the app's main function; problems that seriously compromise or prevent altogether the use of important functions; problems that may have drastic consequences; and major security flaws.
- Worrisome: Damages usability in some level – moderate problems involving the app's main function; problems that reduce usability of important functions; and minor security issues.
- Trivial: Only hazards minor aspects of usability – cosmetic problems; problems that reduce usability of lesser functions; and annoying aspects.

The distribution based on problems' gravity reveals what Heuristic is the most troublesome and should be viewed closely. In Figure 18, all Heuristics evaluated are presented with the number of each kind of Usability problems. Although Visibility of System Status and Consistency & Standards appear have many issues, Privacy-related problems look more serious and urgent, this specific Heuristic must be reviewed in its entirety since the discovered issues can be pervasive.

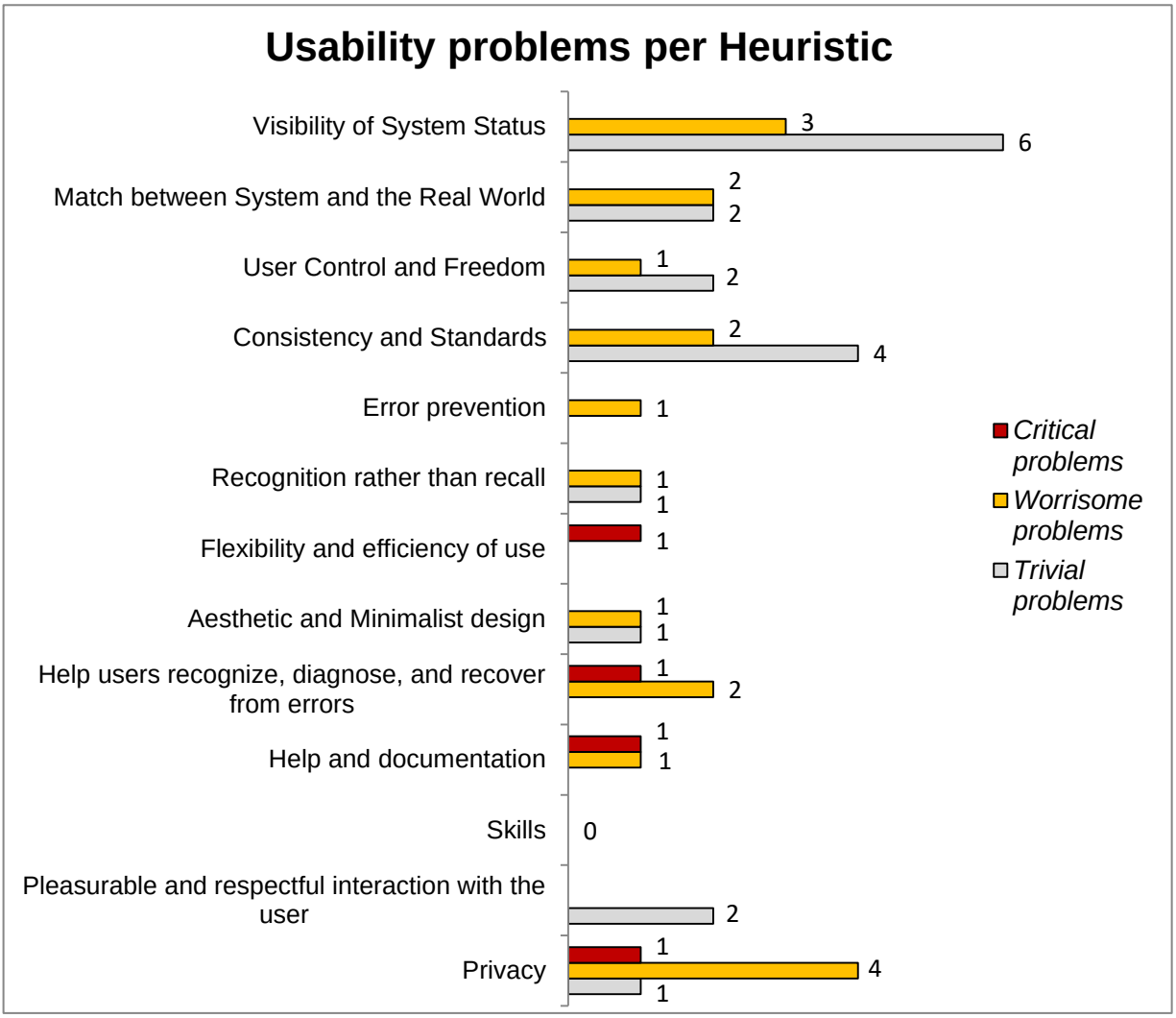

Figure 18 – Classification of Usability problems per Heuristic, detected by HE

Out of a total of 41 identified problems, only 4 were considered critical to the application's Usability: 1) *Anda* is not accessible for people with disabilities – it was considered critical because disabled people cannot use the application altogether due to that; 2) Users are not informed of the severity of errors like turning off NFC, BLE or GPS, especially if considered what can happen to their trip for invoicing purposes or if an inspector comes onboard and requires their ticket – this lack of information might cause confusion and painful situations for users such as fines above €100; 3) *Anda* does not have a "Help" function – although it is valuable to have a minimalistic design, not all target users are digital natives, and even the ones exceedingly familiar with digital technology might find it difficult to understand the functioning of many aspects of the application; 4) When changing the password, the previous password is not required – anyone can change a user's password and that is a major security problemA summary of the critical problems is presented in Table 5.

Table 5 - Critical usability problems on Anda

Heuristic	Problem	Reason to be deemed critical
Flexibility and efficiency of use	No accessibility for disabled people.	Seriously compromise or prevent altogether the use of the application for disabled users.
Help users recognize, diagnose, and recover from errors	Severity of errors like turning off NFC, BLE or GPS is not informed.	May have drastic consequences (fines are above €100 for riding without a valid ticket in *Andante* network).
Help and documentation	No HELP function.	Seriously compromise or prevent altogether the use of the application for some users.
Privacy	Previous password is not asked when changing to a new one.	Major security flaw.

Other 18 problems were considered to be worrisome and the remaining 19 to be trivial. A list of recommendations for *Anda* based on HE's findings is presented jointly with the recommendations from the results of the Usability tests in section 7.2.

6 Usability test

6.1 Test purpose

The purpose of the usability testing was to determine if the *Anda* application is easy to use and navigate for the average user. It was expected that the tests' results would generate valuable suggestions for making the app easier to use and processes such as riding public transport and comprehending invoices quicker and less complicated.

6.2 Sample of Users

The target users of *Anda* are owners of a smartphone with NFC technology and Android Operating System, version 5.0 or higher, who are Metropolitan Area of Porto public transport users. Using personal knowledge, four people who had never had any contact with the application were selected as novice users.

By the time this Usability test was performed, it was already in place a focus group with potential users to strengthen *Anda*'s qualities and find its improvement points. Four people were selected from this group to participate as experienced users; two of them had more than a year of experience, while the other two had between 3 and 12 months. All eight users had an Android smartphone for more than a year when the test took place.

Information on participants' age, sex and knowledge of *Andante* network in Porto is described in Table 6, respectively, based on their experience with *Anda* app.

Table 6 - Demographics of test participants

Age	**Novice users**	**Experienced users**	**Sex**	Nov. users	Exp. users	**Knowledge of *Andante***	Nov. users	Exp. users
18-29	3	1	**Male**	2	2	**Little or Inexistent**	0	0
30-44	1	0	**Female**	2	2	**Reasonable**	1	0
45-59	0	2				**Good**	2	2
60 or more	0	1				**Very good**	1	2

6.3 Test Environment and Role of the Administrator

Since a public transport mobile ticketing solution was being evaluated, the tests were performed in context. In all cases, the test has started in a light rail station previously chosen by the user and ended in another light rail in downtown Porto, either Trindade or Aliados. The final destination was also decided by the users.

The test administrator was responsible for presenting the application to users, explaining the test purpose and how it would go, asking for permission to record audio, reading the questions in the test form and writing down users' answers and comments and his observations on their behaviour towards the application. The administrator could only give hints as to how to finish a task if the user could not complete it alone. After testing, the administrator made an open

interview with users in order to get their opinions, insights and highlights on what is best and worst about the application.

6.4 The Test

The test consisted in three parts. The first part was about gathering participants' information, specifically their names, emails, mobile phone numbers and level of experience with an Android operating system, *Andante* network and *Anda* application.

Second part consisted in asking the users to perform a set of tasks while thinking aloud. They were timed on each task to confirm that tasks did not exceed a reasonable maximum duration. After finishing a 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, as presented in Table 7. The option for an even number of answers in this scale was intentional to prevent respondents from choosing midpoint as a way of avoiding decisions or giving neutral-impressions about a function.

Table 7 - Scales of comprehensibility and utility

Scale	Comprehensibility	Utility
1	Not understandable	Useless
2	Barely understandable	Barely useful
3	Easy to understand	Useful
4	Very clear or Obvious	Very useful or Essential

Tasks were presented with the same configuration in the test form as in Table 8. The following table also contains an example of reply given by a participant.

Table 8 - Example of Usability test task

2. Register in the application	
Time (seconds)	104 s
Comprehensibility (1 to 4)	4 (Obvious)
Utility (1 to 4)	3 (Useful)
Comments (user's verbal comments, errors in selecting menus, difficulties…)	The user did not have any difficulties in registering, but expressed irritation as the process was dull and took too long.

Payment function could not be tested properly as the Usability tests occurred almost at the same time of HE in a beta version of *Anda*, before official launching, so trips did not generate any kind of invoices. The task "Register in the application" was the only one that was not asked for all participants, only to the four first-time users, because the others had already done it and could not create another registration.

Third part of the test was an interview with focused questions and open answers to extract participants' overall opinions and ideas from users regarding the application usability. Most of their observations were restatements of what had been already noted during the second

part, others were suggestions for new functions that would certainly expand *Anda*'s value proposition and hence require new usability studies. Examples of questions included:

- What did you think of *Anda* mobile application?
- What did you like the most about the app?
- What did you find confusing or difficult using the app?
- What did you think of the app's safety?

The complete Usability test form with all three parts is available in Appendix C of this work.

6.5 Results of Usability testing

After tabulating participants' assessment of comprehensibility and utility of functions used to perform the required tasks from the test form, the results are presented in Figures 19 and 20, and explained in detail in this section. Most tasks were accomplished in a matter of a few seconds, and even the ones that required more effort (e.g. registering, changing personal info, etc.) did not take longer than 2 minutes to be accomplished by any of the participants.

6.5.1 Starting the app

Function "Starting the app" consisted in opening the application and the process for doing so, as predicted, was regarded as obvious and essential for using the application by all participants. No further comments were given concerning it.

6.5.2 Registering

As aforementioned, registration function was only evaluated by novice users. The process was deemed as obvious and very useful. Only one participant had complaints about it being too long and dull, implying that perhaps not all information required is really necessary. All participants seemed to believe that all fields in the registration screen were mandatory as there was no indication of optional fields, which is a usability problem as there are optional fields indeed.

6.5.3 Starting a trip

Function perceived as essential to the app, but there was divergence between novice and experienced users about its comprehensibility. Novice users felt that this function was only easy to understand and not obvious given that: 1) the command to start to hold the phone close to a validator is rather dim (as in Figure 10, in section 3.4) and hurried users might not pay attention to it; 2) in case a validator does not recognize the smartphone – a recurrent situation, but considered a technical problem –, there is no indication on what should the user do to start a trip.

6.5.4 Following the trip (a)

Function "Following the trip" was divided in two subfunctions, the first one (a) related to tracking the user's route, as in the lower part of Figure 11, in section 3.4; the second (b) related to the white rectangles in the higher part of the same figure.

Following the trip (a) was considered somehow useful and quite understandable among participants, but a first time user raised concerns about the inability to distinguish between this being their route or just their current location until the moment they start moving to another station. As a suggestion, a participant wanted to be informed of what travel ticket (and how much) was being charged for the ongoing trip.

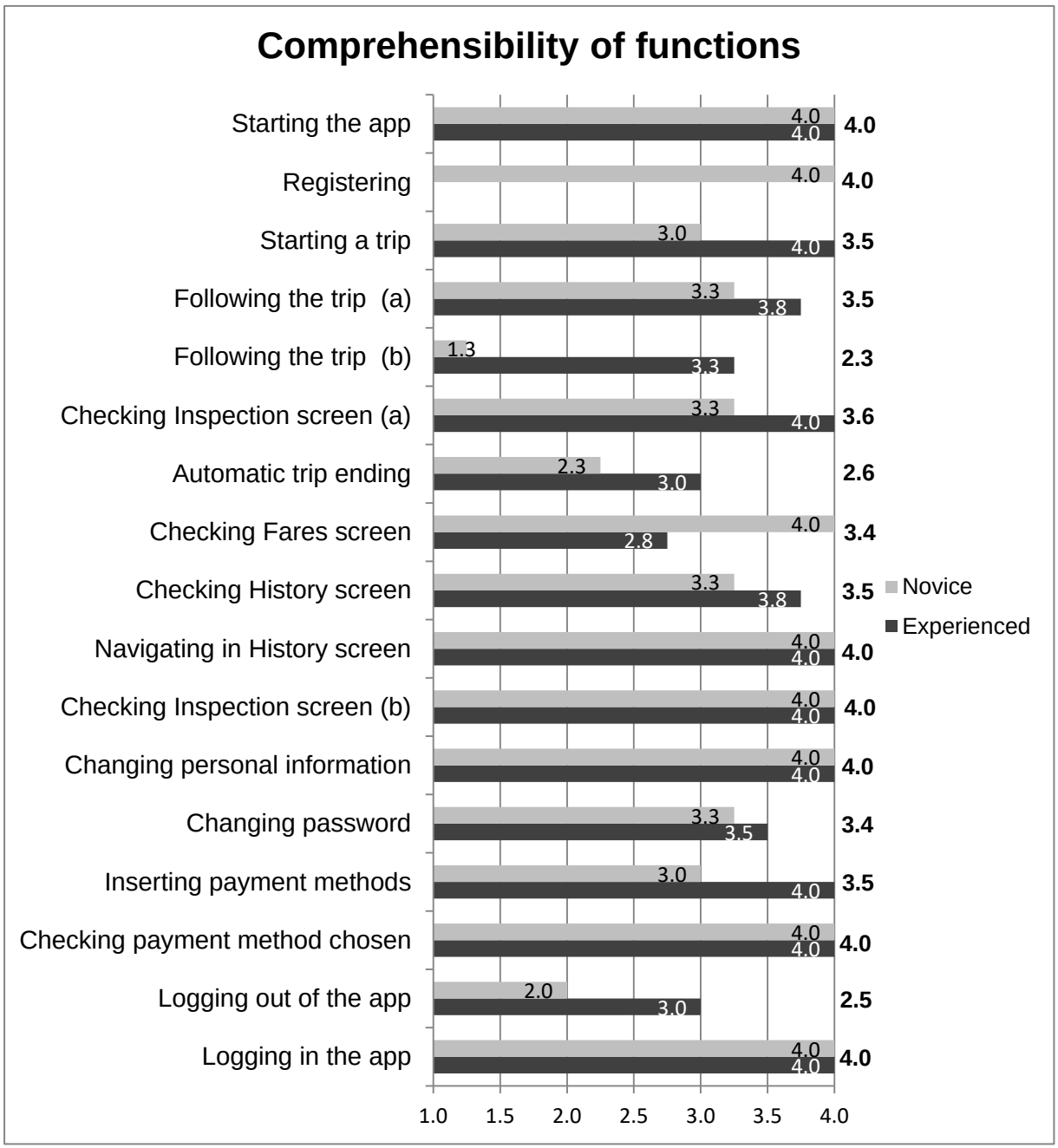

Figure 19 - Perceived comprehensibility of Anda's functions

6.5.5 Following the trip (b)

This subfunction was viewed as barely understandable if the global average is taken into account. However, first-time users viewed the white rectangles as incomprehensible. These rectangles' purpose is to indicate public transport close to the user, the Bluetooth signals which buses or light rail/ suburban train stations are close by. After explaining what they were for, all users agreed that this function was either useless or barely useful.

For a novice user using the light rail underground, it seemed to just repeat location information. An experienced user noted that during bus rides, many bus lines appear and disappear in the rectangles and this might cause confusion. A suggestion was made for the

app dropping this Bluetooth-related function and adding real time information about the next lines in the current station/bus stop.

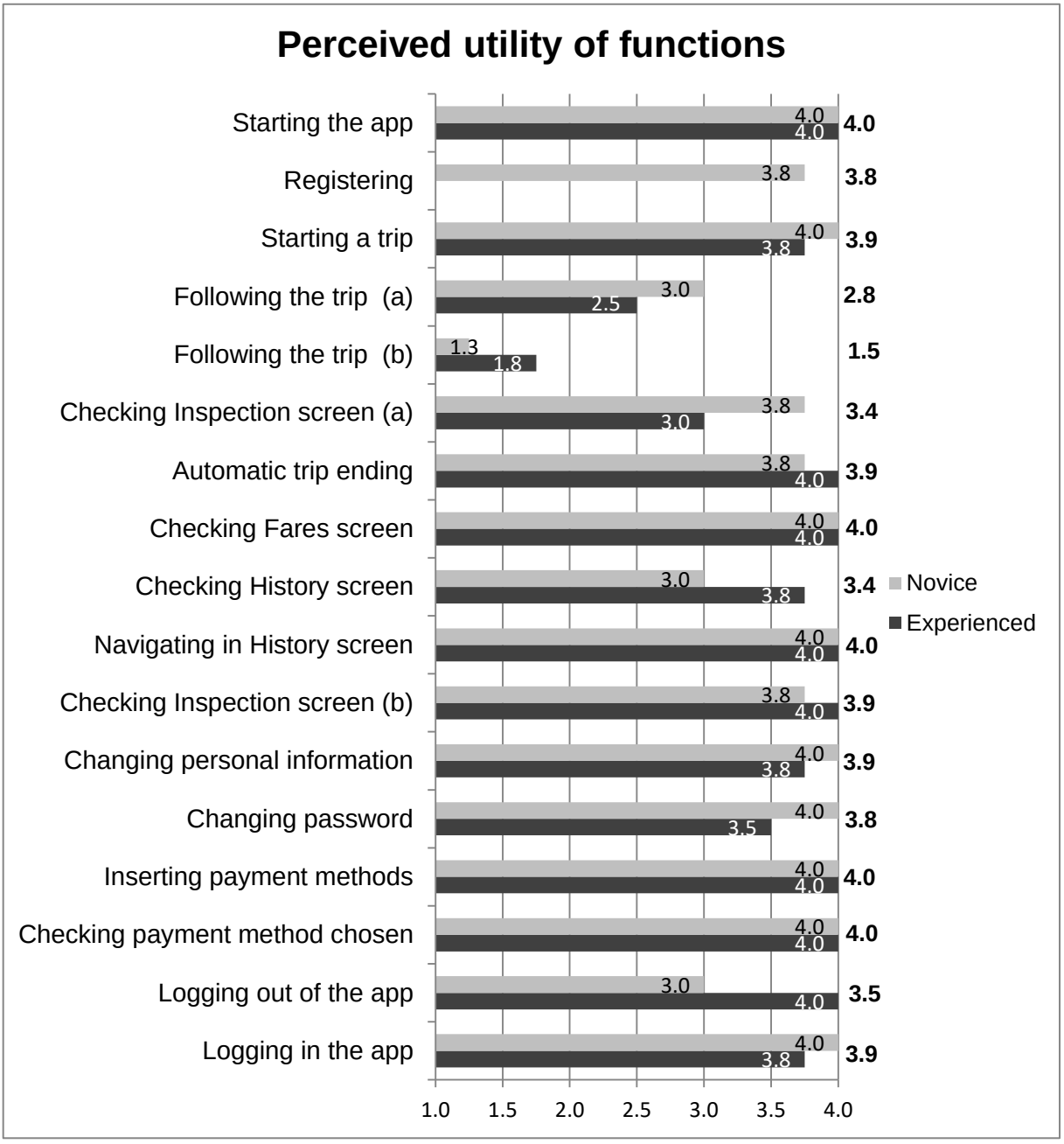

Figure 20- Perceived utility of Anda's functions

6.5.6 Checking Inspection screen (a)

Function "Checking Inspection screen" was also split in two as this screen has two different views: one during a trip (a), presented in Figure 21, and the other when not on a trip (b).

Checking Inspection screen (a) was perceived as, in average, easy to understand and useful by the users. However, experienced users highlighted that this function's utility is not for them but for inspectors. Novice users had a hard time finding the inspection screen as the icon, for them, is not clear.

6.5.7 Automatic trip ending

Because Porto public transport has a Check-in Be out system, *Anda* had to adapt to that through a solution that detected that users finished a journey and then automatically ended it in the app, as explained in section 3.1. This way, users do not have to worry about manually closing it. Test participants found this functionality to be quite useful as it maintains *Andante* network logic.

Notwithstanding, the lack of explanations about this automatic end can confuse users, especially new ones, as it will not be clear what has happened to their journey in the app.

6.5.8 Checking Fares screen

This function was uncommon because it was more understandable for first-time users than it was for experienced ones. This particularity was due to experienced participants had a much larger number of trips, and their Fares screen was much more congested, like in Figure 12, in section 3.4. Novice users only had one trip hence it was simple to understand. All participants found this function very useful.

Participants felt like there should be more information about how fares are grouped by travel tickets and that it is a dynamic fare which can change over time due to optimization of fares.

6.5.9 Checking History screen

This function is presented in Figure 22. Test participants assessed it a useful and easy to understand function. There were concerns, especially by new users, that the information from History is a repetition of Fares, just without indicating fares, and a merger of them was suggested. For experienced users with more packed travel history, it was necessary to scroll down a lot of times in order to reach the beginning of the month. As a suggestion, this screen should also have expandable menus, but instead of by travel ticket type it should be by date.

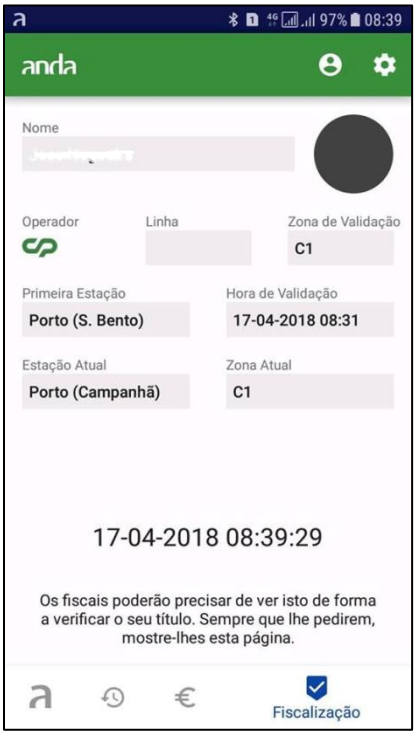

Figure 23 - Anda Inspection screen (on travel)

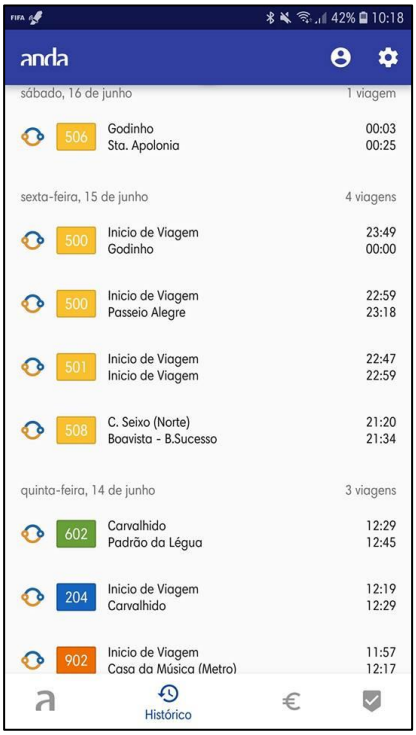

Figure 21 - Anda History screen

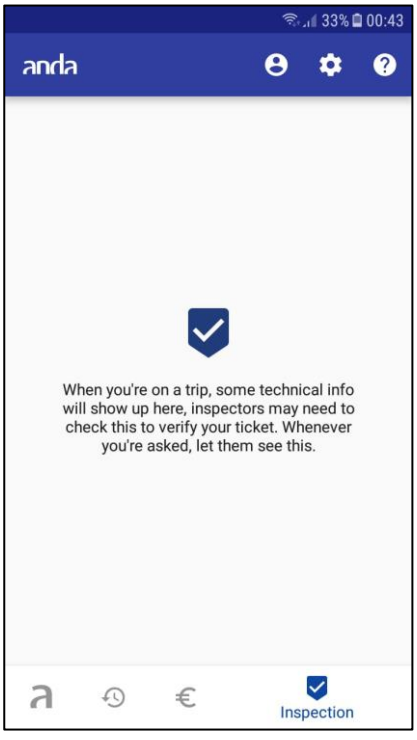

Figure 22 - Anda Inspection screen (out of travel)

6.5.10 Navigating in History screen

Still in History screen, and just like in Fares screen, users can navigate to check their activity in previous months through a header, as shown in Figure 12, in section 3.4. However, this header is not fixed on top, that is, whenever a user scrolls down the header disappears, as in Figure 22. In spite of that minor issue, all participants evaluated this function as obvious and very useful.

6.5.11 Checking Inspection screen (b)

Complementing Inspection screen function, participants evaluated the Inspection screen while not in a trip as very clear and very useful. An example of this screen is in Figure 23.

6.5.12 Changing personal information

This function was readily understood by all participants, who found it obvious. Only one participant did not find this function essential and assessed it as only useful. This participant believed that this kind of information should not be easily changed.

Personal data was all visible in the same Profile screen (name, e-mail, phone number, address, postal code and fiscal number). This was worrisome for three participants who felt vulnerable and wanted this information to be protected in some way.

6.5.13 Changing password

Changing password was a task that startled many participants. All participants showed dissatisfaction when realized that characters were not hidden as they typed. Six of them felt uneasy by the fact that their previous password was not asked before changing into a new one. Two participants also noticed the lack of good practices of confirming the new password by typing it again.

Anyhow, participants evaluated the task as easy to understand and very useful. The most relevant incident was participants not noticing the three dots menu in the right superior corner of the profile screen. As a suggestion, it could become more visible if changed to a three bars menu.

6.5.14 Inserting payment methods

This function was regarded as easy to understand but not completely obvious because: 1) it lacks an action verb (“Insert payment method” instead of just “Payment method”); 2) there is no actual information on how invoices will be sent or in which frequency; 3) there should be a Help button. All participants considered this function to be essential.

6.5.15 Checking payment method chosen

This is a complimentary function to the previous one. Users had to touch an area entitled “Check payment method” below the previous one. All participants found this to be essential and obvious. Some of them said they would rather have a separate section for payments, not together with all personal data.

6.5.16 Logging out of the app

Logging out was considered in average a very useful function but with a barely understandable process. Participants stated that this function was concealed within the app, in an unexpected location (inside Profile), and it should be accessible from home screen.

6.5.17 Logging in the app

Logging in the app after logging out went without setbacks for almost all participants, so it was considered an obvious and very useful function. However, because there was no confirmation after changing the password, one of the participants could not log back in the app and it was noticed that it lacked a "Forgot my password" option in login screen.

6.6 Usability problems detected

After reviewing the results of Usability tests and comments provided, 34 Usability problems were detected. In order to facilitate comparison between issues found by both usability evaluation methods, problems coming from the tests were classified by Heuristics and then divided in the same three categories depending on how much they affected the use of the application (Critical, Worrisome or Trivial).

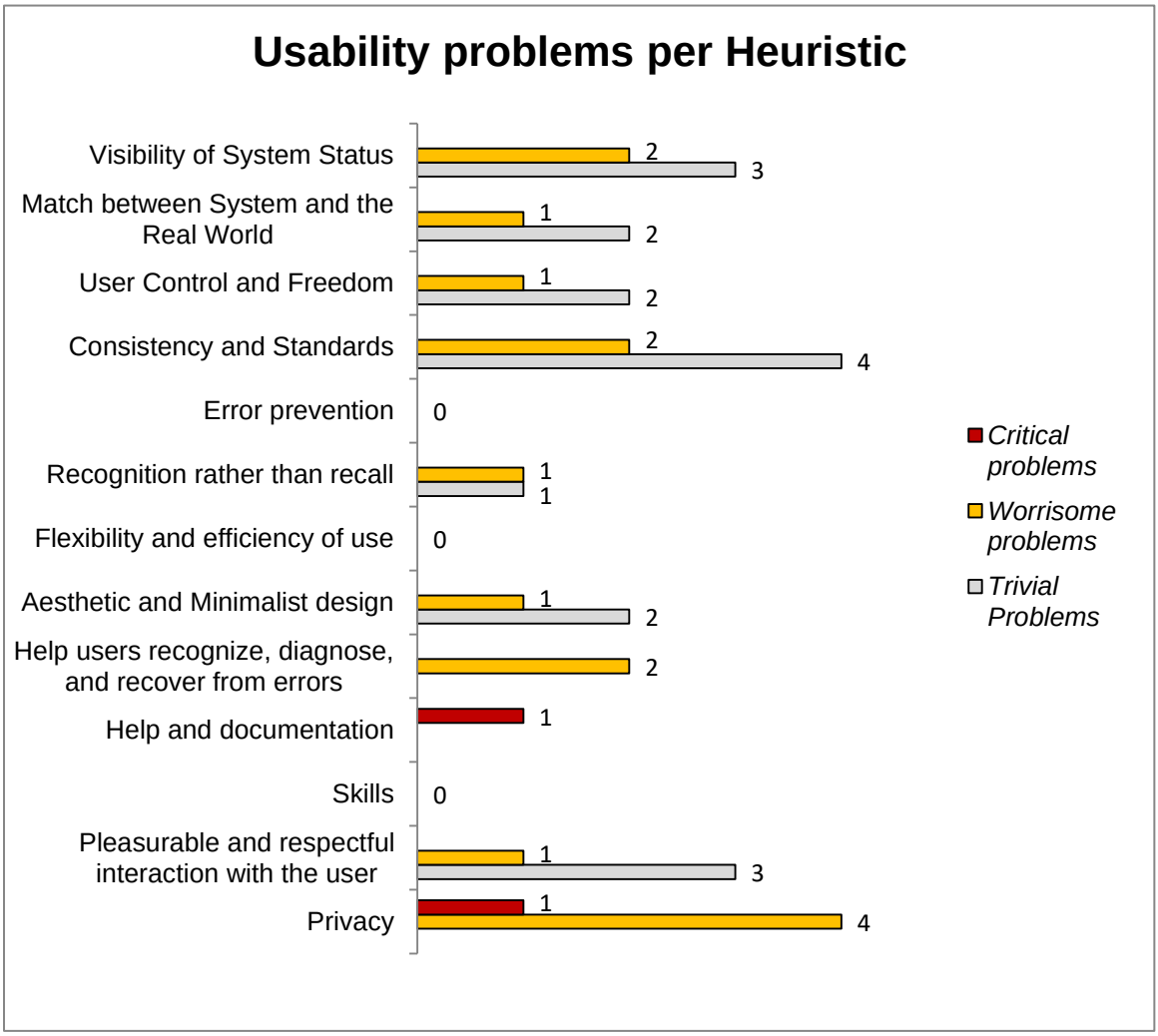

Figure 24 - Classification of Usability problems per Heuristic, detected by Usability testing

Out of a total of 34 identified problems, 2 were considered critical to the application's Usability and all of them had been already detected by Heuristic Evaluation: 1) Anda does not have a "Help" function; 2) When changing the password, the previous password is not required. Other 15 problems were considered to be worrisome and the remaining 17 to be trivial. A list of recommendations for Anda based on the results of the Usability tests is presented jointly with the recommendations of HE's findings from in section 7.2.

Distributing problems based on their seriousness and their related Heuristic gives a better overview on what is most concerning. Figure 24 is purposely similar to Figure 18 from section 5.3. Again, just as in HE, although Consistency & Standards concentrates the largest amount of issues, most of them are Trivial and can be overlooked until Privacy-related problems are taken care of, due to the latter being much more relevant and urgent.

7 Evaluation and Discussion

In this section, the results of both the Heuristic Evaluation (HE) and Usability tests of *Anda* are presented, analyzed and compared. Then, recommendations regarding usability issues are made for *Anda* based on findings. Finally, after a revision, a final Heuristic checklist for public transport mobile ticketing solutions is proposed.

The goal here was to synthetize, in an organized way, the information that satisfies the general and specific objectives of this work.

7.1 Results comparison and analysis

Analyzing results that arose from HE and Usability tests, there were in total 57 problems detected by the two evaluation methods combined after eliminating duplicates, being 4 of them critical, 22 worrisome and 31 trivial. The full list of Usability problems detected on *Anda* is available in Appendix A.

HE provided with 23 unique problems, being 2 of them critical, 7 worrisome and 14 trivial. Usability tests provided with 16 unique problems, being 4 of them worrisome and 12 trivial.

A sum of 18 problems was identified by both methods, being 2 of them critical, 11 worrisome and 5 trivial. This information is summarized by Figure 25.

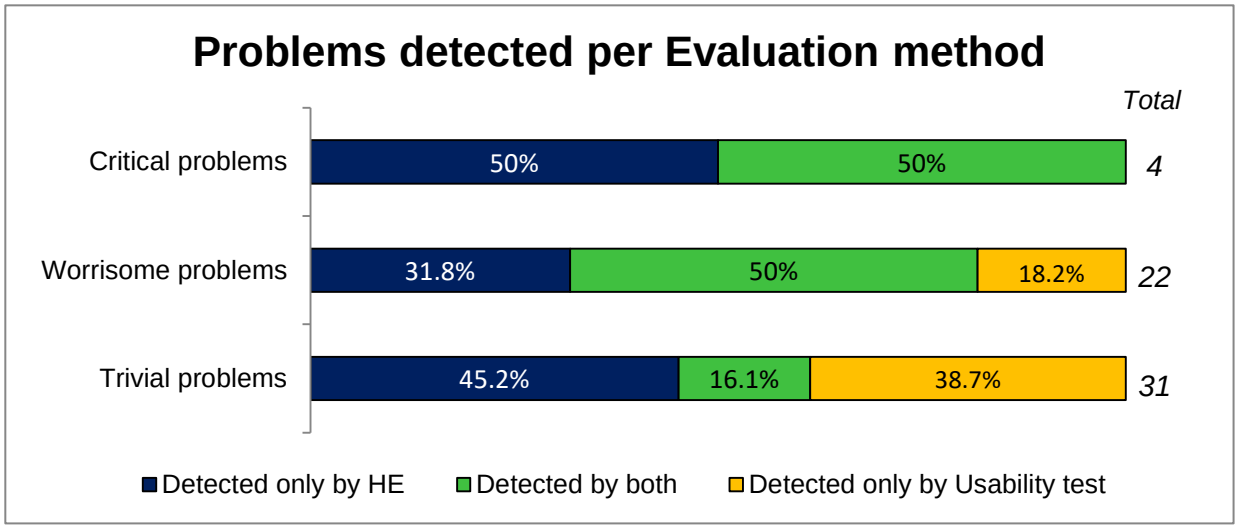

Figure 25 - Problems detected per Evaluation method

By looking at the gravity of problems detected by each method, it is clear that HE was more successful in identifying major issues: 100% of critical and 81.8% of worrisome problems. This implies that the Heuristic checklist developed for public transport mobile ticketing solutions was very effective in identifying what matters the most.

Usability testing still complemented 18.2% of worrisome problems with new findings. Even though it was not much and no critical issues were missed, worrisome problems can affect usability significantly and should not be taken lightly. This indicates that the Heuristic checklist still had to be upgraded before being accepted.

Analyzing detected problems per heuristic type in Figure 26, the focus of each method becomes more evident. Issues with Visibility of System Status were prevalent through HE since it identified 9 occurrences against 5 through Usability testing out of a total of 10. In the other hand, the latter method was notably efficient in detecting problems with Pleasurable & Respectful Interaction, 4 against 2 in a total of 6. HE was also remarkably deficient in discovering problems related to Consistency & Standards – even though 6 were discovered, other 4 were missed – and to Aesthetic & Minimalist Design.

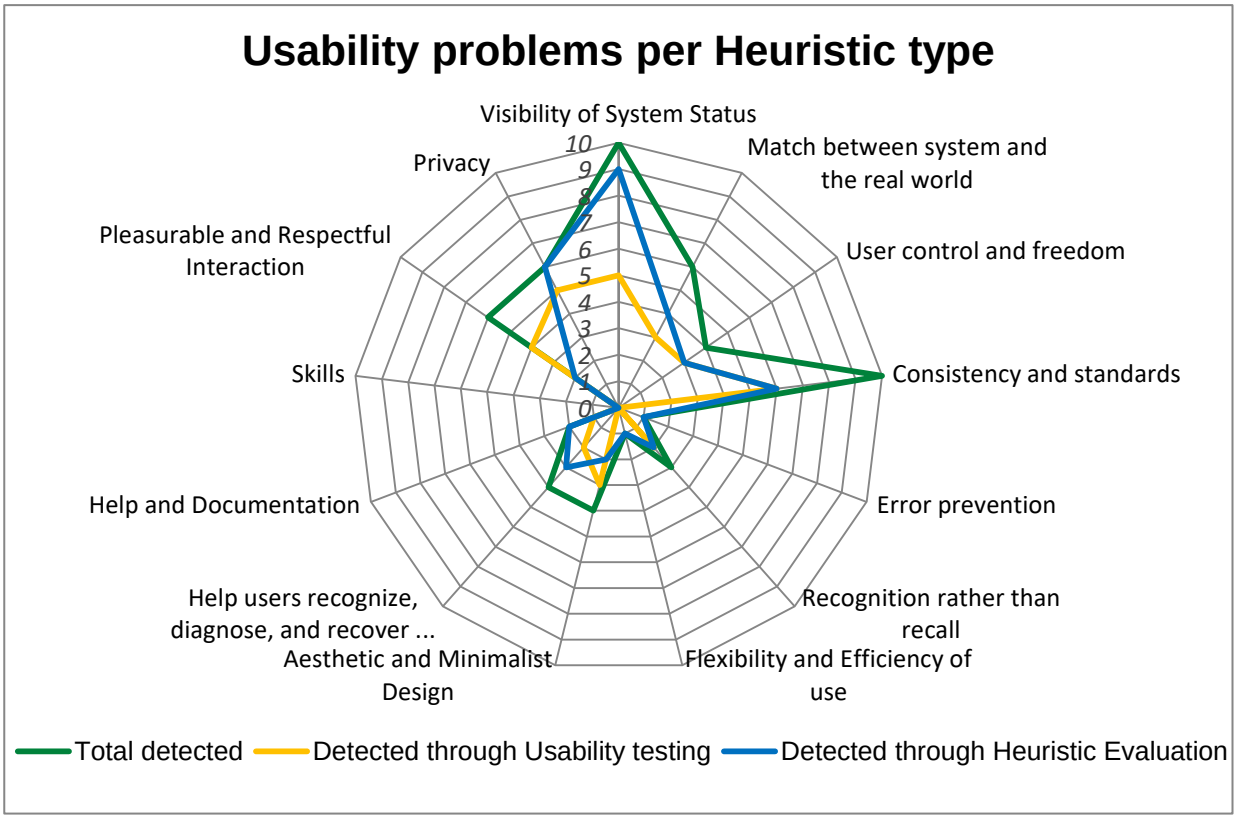

Figure 26 - Comparison of methods by usability problems detected per Heuristic type

A higher frequency of Visibility of System Status problems in HE can be explained by the fact that evaluators were usability experts who had experience in noticing this kind of issues in a glance, while regular users were, in general, deeply absorbed in interaction aspects.

These observed limitations of the Heuristic checklist needed to be undermined in order to be more productive in these areas and grant adequate and broad contributions in all directions for public transport mobile ticketing solutions development. An adjusted Heuristic checklist was proposed in section 7.2 with adjustments and some new subheuristics with this purpose.

In any case, the HE was more practical than Usability testing both in a perspective of relevance and number of results produced and in a perspective of time needed to effectively perform evaluations, as HE required half the number of participants.

7.2 Recommendations for *Anda*

After analyzing usability problems detected along this study, a far-reaching list of 51 recommendations for *Anda* organized by order of importance was proposed in Table 9.

Importance criteria directly derived from classification in critical, worrisome and trivial problems.

Total number of recommendations does not match the sum of problems because some recommendations solve more than one problem at once.

Table 9 - List of usability recommendations for Anda

#	Recommendation	Importance
1	Right after a trip starts, inform users to not turn off NFC, BLE or GPS and clarify possible consequences of doing so.	*High*
2	Make Anda accessible for disabled people.	*High*
3	Add a Help function. Other help information can be added along specific screens.	*High*
4	Demand for the previous password before allowing to change to a new one.	*High*
5	Place tabs on top or a more visible location.	*Medium*
6	Explain about dynamic prices decribing how they may change after some travels.	*Medium*
7	Provide information at the "Start a trip" screen about what to do in case a validator does not recognize a mobile phone or takes too long to validate.	*Medium*
8	Substitute "Fares" for "Invoices" as the tab name.	*Medium*
9	Substitute the Inspection icon for something more readily understood.	*Medium*
10	Place Log out in home screen.	*Medium*
11	Add a "Forgot my password" option in the login screen.	*Medium*
12	Use abbreviations consistently. (e.g. Either abbreviate "Hospital" as "H." or "Hosp.", do not use both.)	*Medium*
13	Place Send Report in Settings or in a new menu for Help & Support.	*Medium*
14	Present information of zones in past trips.	*Medium*
15	Have a clearer form of displaying past trips when they are grouped in a single journey.	*Medium*
16	Do not reset password without user's consent in any circumstance.	*Medium*
17	Mark errors in a form.	*Medium*
18	Display error messages for a reasonable time or keep all of them until dismissed.	*Medium*
19	Add more forms of payment.	*Medium*
20	Offer to keep personal data protected by password.	*Medium*
21	Enable deleting travel history from mobile phone. Explain that it will be kept in *Anda*'s system for invoicing purposes.	*Medium*
22	Confirm a new password after changing the old one.	*Medium*
23	Hide characters when changing the password and allow users to see it if they want.	*Medium*
24	Enable to swipe between tabs.	*Low*
25	Emphasize the message "Hold your phone close to a validator", in Start a trip	*Low*

	screen.	
26	Explain about the latest automatic trip ending at the first moment a the user interacts with the app again after it ends.	*Low*
27	Add an indication of current travel ticket in place during a trip.	*Low*
28	By tapping in Version, present information about or a link to app developers.	*Low*
29	Provide some visual feedback after tapping profile or settings, so the user knows it was not a missed tap.	*Low*
30	Do not show the users' complete route in totality while on a journey. Recommend to show only origin, current station/bus stop, Andante zones past and travel ticket type or price.	*Low*
31	Have "Name" and "Surname" fields, so that users understand that their real and full names are required.	*Low*
32	Substitute "Payment method" for "Choose payment method" in the option for choosing payment method.	*Low*
33	Always identify the light rail lines taken.	*Low*
34	In Portuguese, substitute "Viajar" for "Viagens".	*Low*
35	Back button should work to return to a previous tab, not only from deeper menus to home screen.	*Low*
36	Some level of personalization should be available.	*Low*
37	Information in History and Fares should be consistently displayed in the same order.	*Low*
38	Never call the password by other names, such as "keyword".	*Low*
39	Place Change password in Settings.	*Low*
40	Do not use dark grey, use black or light grey instead.	*Low*
41	After tapping a field in profile, do not open a prompt for editing.	*Low*
42	Place Payment Methods in a separate menu of its own, accesible from home screen.	*Low*
43	Clearly mark optional data entry fields.	*Low*
44	Make the application more prominent.	*Low*
45	Remove white rectangles altogether.	*Low*
46	Offer to keep login information.	*Low*
47	Add expandable headers in History the same way as in Fares.	*Low*
48	Keep drop-down month/year menu fixed on top of History and Fares screens when user scrolls down or make it reappear right after a short scroll up.	*Low*
49	Enable more types of notification.	*Low*
50	Allow users to choose to see the password clearly in login screen.	*Low*
51	Inform users how personal data is protected and used.	*Low*

As a form of exhibiting the guiding ideas underlying recommendations for *Anda*, three mock-ups were created modifying and adding elements based on the layout of the application latest versions. Mock-ups are depicted in Figures 27, 28 and 29.

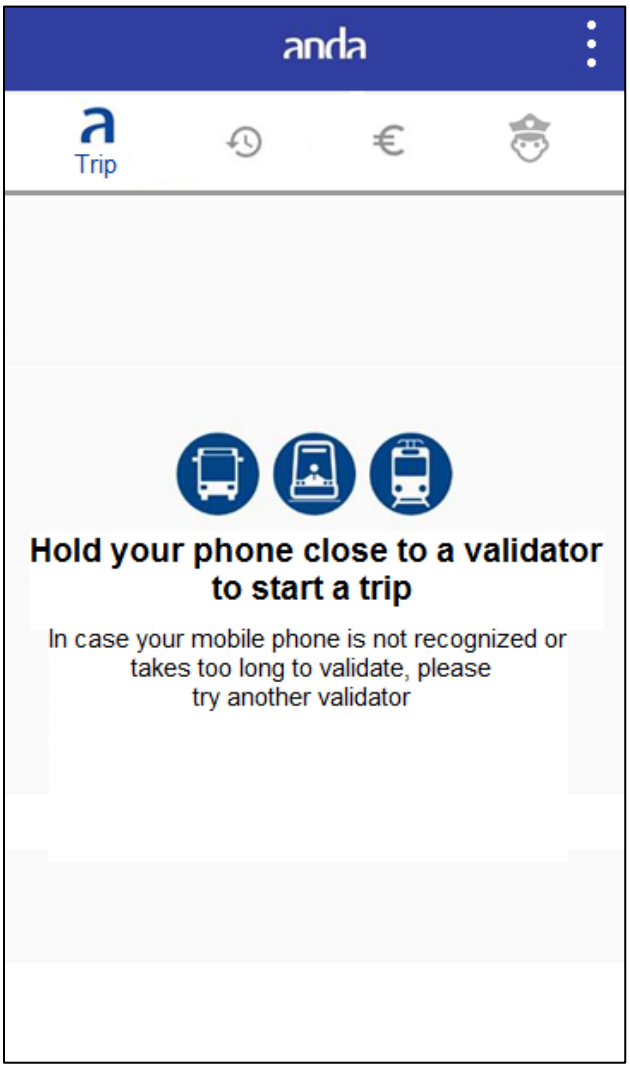

Figure 27 - Anda Home screen mockup

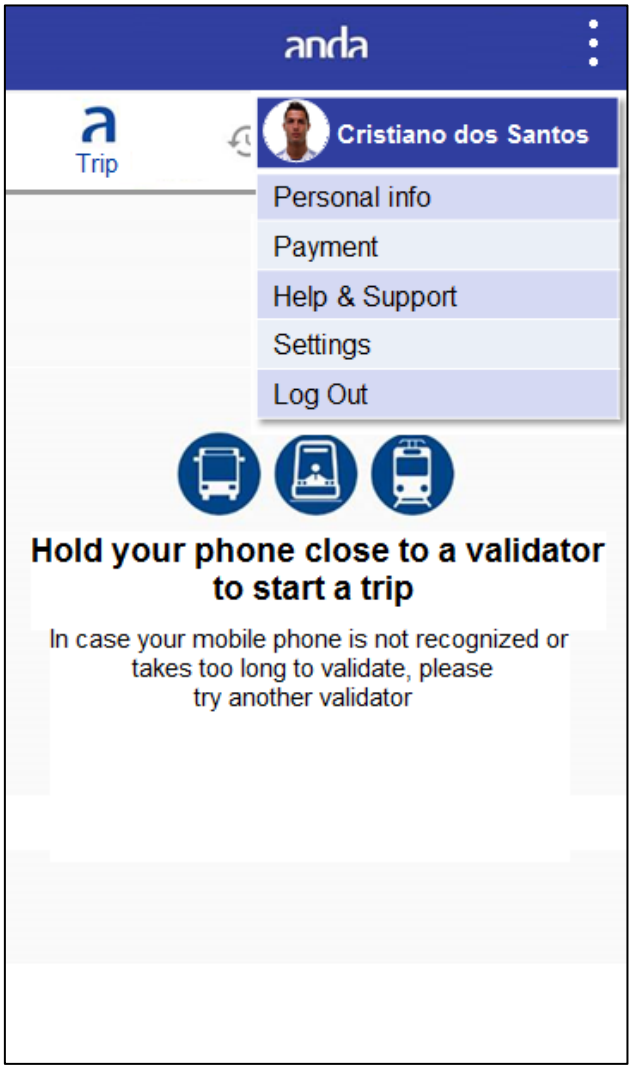

Figure 28 - Anda Home screen with menu mockup

In Figure 27, recommendations 5, 7, 9, 25 and 40 are put in place in Anda home screen. The tabs were placed in on top to become more visible; there is information available in case a validator does not recognize or takes too long to validate a mobile phone; the inspection icon was replaced by a more readily understood one; the message to hold the phone close to a validator is stressed; and dark grey is completely replaced by black or light grey.

In Figure 28, recommendations 3, 10 and 42 are implemented in Anda home screen through a 3 dots menu placed on top-right corner. Profile and Settings go inside this menu. Log out was made available from home screen, a Help & Support function was added and Payment is separated from Personal information.

In Figure 29, recommendations 1, 27, 30 and 45 were implemented in Anda travel screen, that is, the home screen while on a trip. Users get a notification explaining the severity of turning off NFC, BLE or GPS; information regarding travel ticket being used during a trip was added; users' complete route was hidden as it was deemed unnecessary and only start and current/ final positions shown; white rectangles were removed altogether.

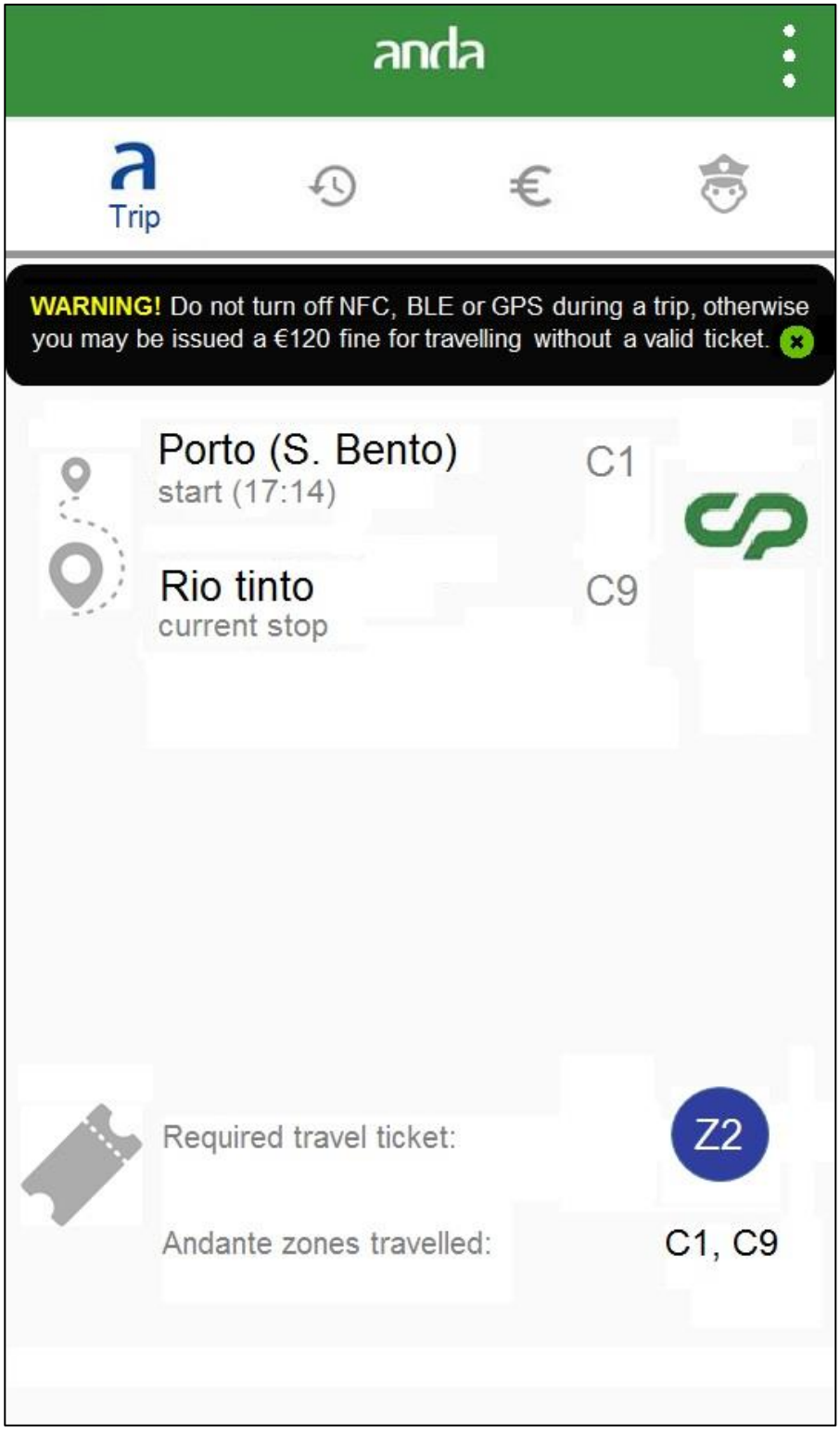

Figure 29 - Anda Travel screen mockup

7.3 Adjustments to the Heuristic checklist for public transport mobile ticketing solutions

According to section 7.1, three Heuristics of the checklist were particularly feeble in finding usability problems, not because they were not found, but because there was a significant gap

between HE's results and total number of problems. These Heuristics were Pleasurable & Respectful Interaction, Consistency & Standards and Aesthetic & Minimalist Design.

Keeping these points of improvement in mind, a new set of questions focused on the aforementioned Heuristics is proposed in Table 10 to be added to Checklist (in Appendix B), so that it becomes more solid and unerring.

Table 10 - Adjustments to the Heuristic Checklist

Heuristic	Subheuristics to be added to Checklist
Consistency & Standards	Does travel history appear in a consistent manner across screens?
	In screen that require password (e.g. login screen), is there a "Forgot my password" option?
	Do the options inside a menu fit incontestably in it rather than in another (existing or new) menu?
Recognition rather than Recall	Does travel history keep all (and only) relevant information?
Aesthetic & Minimalist Design	Are all menus and screens essential and make sense to remain separated? (Sometimes, merging menus/screens shall be cogitated).
Help users recognize, diagnose, and recover from errors	After two failed password attempts, does the app warn user that in case of a third consecutive fail there will be consequences? (e.g. temporary account lockdown unless password is reset).
Pleasurable & Respectful Interaction	When logging in must be done, is there an option to keep login information to make it faster and easier?
	In screens with a higher load of information, are items grouped by expandable headers? (Instead of displaying items in long vertically scrollable screens).
	Are all drop-down menus fixed on the screen even if the user scrolls down? If they disappear, do they reappear right after a short scroll up?

For creating this new set of questions, the list of usability problems identified (available in Appendix A) was used. The 16 issues detected without the Heuristic Checklist were screened and studied. It was concluded that 7 of these problems, 1 worrisome and 6 trivial, could have been identified using the Checklist and the reason why one worrisome problem got through was because Payments function was not working properly yet by the time the Heuristic Evaluation was conducted; *Anda* was in a beta version. Then, new questions were added for the other 9 undetected usability problems.

8 Conclusion

The work about Usability evaluation methodology for public transport mobile ticketing solutions achieved its general objective: Construct and validate a context-specific usability evaluation methodology that will produce artifacts applicable for public transport mobile ticketing solutions. The methodology was presented, put into practice and evaluated, producing usability artifacts.

Regarding the specific objectives, it was formulated a list of Heuristics and a Checklist for Public transport mobile ticketing solutions and, from that, it was performed a Heuristic Evaluation (HE) of *Anda* application, Porto public transport mobile ticketing solution, however, because it was a beta version of the app not yet available for the general public, some functions were not completely functional.

The list of Heuristics developed in this work contributes to development of the research area and literature by creating a new context-specific record in Usability.

Additionally, Usability tests were performed on *Anda* in context of public transport to complement HE in making recommendations for usability improvements of the app. Users provided feedback on their perceived comprehensibility and utility of app functions in a scale from 1 to 4, being 1 the lowest and meaning "Not understandable" and "Useless", and 4 the highest and meaning "Very clear or Obvious" and "Very useful or Essential".

A sum of 57 usability problems was identified by HE and Usability tests together, 4 of them being considered critical, 22 worrisome and 32 trivial. Problems were considered critical if seriously decayed usability; worrisome if they damaged usability in some level; and trivial if they only hazarded minor aspects of usability.

A comprehensive list of recommendations for *Anda* was forged based on the aforementioned issues, stressing the urgency of each one of them. Mock-ups were created to illustrate some recommendations, especially the ones involving layout changes.

Usability tests' results were also used for evaluating the formulated Heuristic checklist's performance. Although HE, using the Checklist, found more problems than Usability tests did (41 x 34) and detected the 4 critical ones, it still missed 16 (4 worrisome and 12 trivial). Therefore, adjustments to the Checklist were proposed with new questions introduced focusing on the Heuristics with lower efficiency.

At the end of this research, from observing results, it became evident that public transport mobile ticketing solutions field is a fast-growing one that can benefit a lot from usability studies and evaluations.

This work aimed to contribute to better usability evaluation that would meet specific requirements of public transport mobile ticketing solutions and, as a consequence, make it easier developing and improving such solutions; and to detect *Anda*'s usability problems and enhance its overall usability through recommendations, thus increasing user experience and satisfaction with the app, helping to upsurge its initial adoption and to maintain the user base after it reaches a well-established position in Porto public transport system.

In view of the study carried out, the methodology applied and the results obtained, it was possible to propose an opportunity for deepening and developing future works by applying

this methodology in other public transport mobile ticketing applications or in developing context specific Heuristics to other fields.

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APPENDIX A: Full list of Usability problems detected on *Anda*

Heuristic	Usability problem	Importance
Visibility of System Status	Screen does not swipe as it seems to do by having tabs	Trivial
	The message "Hold your phone close to a validator" is dull.	Trivial
	Automatic trip ending is not explained anywhere. Users have to guess what happened.	Trivial
	There is no indication of what type of travel ticket is being used in a trip.	Trivial
	There is no link to or information about the enterprise, company, app developers, etc.	Trivial
	It is not possible to contact the enterprise.	Trivial
	When tapping profile or settings, there is no visual feedback.	Trivial
	Showing stations/ bus stops along the way is unnecessary. Only start point, Andante zones in the way and end point matter.	Trivial
	Tabs stand at the bottom, making them less visible and harder for users to locate themselves in the app	Worrisome
	Dynamic fares are not explained. Users are not informed that there is optimization algorithm that calculates the best fare and might worry that prices change.	Worrisome
	In case it takes time to validate/start a trip, there is no feedback on the progress or indication of what users should do.	Worrisome
Match between system and the real world	During registration, it is not clear if "Name" means full name, first name, made-up username, etc.	Trivial
	Language is not clear in "Payment method". It lacks an action verb.	Trivial
	The subway line name and colour is identified only in certain occasions.	Trivial
	In Portuguese, "Viajar" is not parallel gramatically with the other tab names.	Trivial
	Neither "Fares" nor "Tarifas" are accurate names for what the tab represents.	Worrisome
	Inspection tab icon is not readily clear.	Worrisome

User control and freedom	"Back button" does not work properly for in-app navigation.	Trivial
	There is no room for personalization.	Trivial
	There is a deep menu in "Profile".	Trivial
	Exits are not clearly located. Logging out is not obvious.	Worrisome
Consistency and standards	Inconsistent order of trips in "History" and "Fares", one shows most recent trips first and the other shows oldest trips first.	Trivial
	Password is called "Keyword" when a user commits a mistake in typing it during log in.	Trivial
	"Change password" is located inside "Profile". This is not standard.	Trivial
	Use of dark grey and black. These colours are too close in colour spectrum.	Trivial
	In "Profile", tapping a field opens a prompt for editing. This is not standard.	Trivial
	Payments section inside "Profile" is not standard.	Trivial
	Abbreviations are not consistent, e.g. "Hospital" is abbreviated as "Hosp." and "H." (H. São João x Hosp. S. António).	Worrisome
	When logging in, there is no "Forgot my password" option.	Worrisome
	"Send report" inside "Profile" is not standard.	Worrisome
Error prevention	Users are not informed beforehand to remain with NFC, BLE and GPS turned on during the totality of their trips.	Worrisome
Recognition rather than recall	Optional data entry fields are not clearly marked.	Trivial
	In "History", users are not informed thorugh which Andante zones they went through during trips.	Worrisome
	Past trips information is not clear, especially in cases of multiple transfers.	Worrisome
Flexibility and Efficiency of use	No accessibility for disabled people.	Critical
Aesthetic and Minimalist Design	The application icon is rather bleak.	Trivial
	"History" information is mostly a repetition of "Fares".	Trivial
	White rectangles shown during a trip have no function and cause confusion.	Trivial
	Icons do not show labels all the time, only when selected.	Worrisome

Help users recognize, diagnose, and recover from errors	When typing the password to log in, if user commits three mistakes in a row, an automatic change of password is sent to their e-mails without previous warning.	Worrisome
	When filling a form, errors are not marked to facilitate user's understanding.	Worrisome
	When filling a form, error messages are shown very briefly and users do not have time to read them.	Worrisome
	In-app notifications are shown on the bottom of the screen, covering tabs and preventing navigation.	Worrisome
	Severity of errors like turning off NFC, BLE or GPS is not informed.	Critical
Help and Documentation	There is no Help function.	Critical
Pleasurable and Respectful Interaction	Cannot store login information for fast and easy logging in.	Trivial
	A recurrent user's "History" screen is almost always overcrowded with information.	Trivial
	In "Fares" and "History", expandable menu with indication of month and year is not fixed on the top; it disappears when scrolling down the screen.	Trivial
	There is little/no option for turning on/off notificiation sounds and vibration.	Trivial
	When logging in, user does not have an option to see the password clearly.	Trivial
	There is a very limited number of payment methods available.	Worrisome
Privacy	It is not possible to delete travel history.	Trivial
	Personal data is easily accessible.	Worrisome
	There is no information about how personal data is protected, especially for cases of losing the mobile phone.	Worrisome
	New password is not confirmed after changing.	Worrisome
	Characters are not hidden when changing the password.	Worrisome
	Previous password is not asked when changing to a new one.	Critical

APPENDIX B: Heuristics and Guidelines

1. Visibility of System Status

The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.

#	Review Checklist	Yes	No	N/A	Comments
1.1	Is there some form of system feedback for every operator action?[1]	O	O	O	
1.2	Does the system provide visibility: that is, by looking, can the user tell the state of the system and the alternatives for action? (e.g. If there is an active journey, if the user is logged in, if the communications are on, etc.) [1, 2]	O	O	O	
1.3	Are high informative contents placed in high hierarchy areas? [1]	O	O	O	
1.4	Once checked in a journey, is it clear for the user where it was started and with which bus/train?	O	O	O	
1.5	Is it easy for the users to follow the journey with the app: that is, does the app show clearly where did the journey started, which bus(es) or train(s) the user already took during the current journey and in which stop and which bus/train the user is at that moment?	O	O	O	
1.6	Once a journey ends, is the user readily notified of all relevant information regarding it? (Departure and Arrival times and locations, price, etc?)	O	O	O	
1.7	Is the remaining time until the end of the user's current journey visible or at least available for the user to check?	O	O	O	
1.8	Is the logo meaningful, identifiable, and sufficiently visible? [1]	O	O	O	
1.9	Is there any link to detailed information about the enterprise, company, app developers…? [1]	O	O	O	
1.10	Are there ways of contacting with the enterprise? [1]	O	O	O	
1.11	Does every display begin with a title or header that describes screen contents? [2]	O	O	O	
1.12	Does the app start as quickly as possible so that people can begin using them immediately?[3]	O	O	O	
1.13	Does the app display a launch image?[3]	O	O	O	
1.14	Are response times appropriate for the users cognitive processing? [1]	O	O	O	
1.15	Are response times appropriate for the task? [1]	O	O	O	
1.16	If there are observable delays (greater than five seconds) in the system's response time, is the user kept informed of the system progress? [1]	O	O	O	
1.17	Is the average time taken for validation appropriate?	O	O	O	
1.18	Is the current status of an option or icon clearly indicated? [1]	O	O	O	
1.19	Is there clear visual feedback when an option or icon is selected? [1,2]	O	O	O	
1.20	Do all active areas look touchable? (users do not know that something is touchable unless it looks as if it is); [1]	O	O	O	
1.21	If it is possible to swipe through screens, is there a visible cue indicating so? [1]	O	O	O	
1.22	Does the app avoid using expandable menus? If expandable menus are used, do the menu labels clearly indicate that they expand to a set of options? [1]	O	O	O	

2. Match Between System and the Real World

The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order. Metaphors should be easy to understand.

#	Review Checklist	Yes	No	N/A	Comments
2.1	Are the names used in the app self-explanatory? [4]	O	O	O	
2.2	Are icons concrete and familiar? [1]	O	O	O	
2.3	If shape is used as a visual cue, does it match cultural conventions? [1]	O	O	O	
2.4	Do the selected colours correspond to common expectations about colour codes? [1]	O	O	O	
2.5	If buses or subway lines are identified also by colours, besides names and number, are these colours represented in the app? (e.g. If the user takes the D Subway line, which is always depicted in yellow by PTO, then its representation should be yellow in the app as well)	O	O	O	
2.6	Is too much navigation (TMN) avoided? [1]	O	O	O	
2.7	Are menu choices ordered in the most logical way, given the user, the item names, and the task variables? [1]	O	O	O	
2.8	Do menu choices fit logically into categories that have readily understood meanings? [1]	O	O	O	
2.9	Are menu titles parallel grammatically? [1]	O	O	O	
2.10	In navigation menus, are the number of items and terms by item controlled to avoid memory overload? [1]	O	O	O	
2.11	Is the language used the same target users speak? [1]	O	O	O	
2.12	Is the language clear and concise? [1]	O	O	O	
2.13	Does the application follow the rule “1 paragraph = 1 idea”? [1]	O	O	O	
2.14	Does the system automatically enter leading or trailing spaces to align decimal points, times and dates? [1]	O	O	O	
2.15	Does the system automatically enter a currency sign and decimal for monetary entries? [1]	O	O	O	
2.16	Are integers right justified and real numbers decimal-aligned? [1]	O	O	O	
2.17	Are dates complemented by the respective day of the week?	O	O	O	
2.18	Can time preference be switched between 24 hours clock and 12 hours AM/PM according to the user's preference?	O	O	O	
2.19	Are invoices easy to understand?	O	O	O	

3. User Control and Freedom

The system should have (a) clearly marked exit(s) to leave an unwanted state and return to the previous or the top level. Support undo and redo.

#	Review Checklist	Yes	No	N/A	Comments
3.1	Are the exits clearly marked? [1]	O	O	O	
3.2	Is the general app structure user-oriented? [1]	O	O	O	
3.3	Is there any way to inform user in which part of the app they are and how to undo their navigation? [1]	O	O	O	
3.4	Does the "Back" button work for app exploration? [5]	O	O	O	
3.5	Can the users tailor an amount of interactive content: that is, is there some level of personalization available? [5]	O	O	O	
3.6	When a user's task is complete, does the system wait for a signal from the user before processing? [1]	O	O	O	
3.7	Are users prompted to confirm commands that have drastic consequences or even prevent them from using public transport through the app? [1]	O	O	O	
3.8	Can users easily reverse their actions? [1]	O	O	O	
3.9	Is there an easy access to allow users to go back to home screens and previous menus? [1,5]	O	O	O	
3.10	Are menus broad (many items on a menu) rather than deep (many menu levels)? [1]	O	O	O	

4. Consistency and Standards

Follow platform conventions. Use clear, intuitive, commonly known mobile application symbols.

#	Review Checklist	Yes	No	N/A	Comments
4.1	Have attention-getting techniques used carefully and specifically to draw attention, communicate organization, indicate status changes, and establish relationships? [1,2]	O	O	O	
4.2	Are there at most two levels of intensity? [1]	O	O	O	
4.3	Are there no more than four colours and they are far apart along the visible spectrum? (additional colours for occasional use only – up to seven) [1]	O	O	O	
4.4	Are the brand's colours or images incorporated in a refined, unobtrusive way? (The exception to this guideline is the application icon) [3]	O	O	O	
4.5	Are harsh sounds and/or vibration used for only rare critical conditions? [1]	O	O	O	
4.6	Do instructions appear in a consistent location across screens? [1]	O	O	O	
4.7	Have industry formatting standards been followed consistently in all screens within the app? [2]	O	O	O	
4.8	Are there no more than twenty icon types? [1]	O	O	O	
4.9	Has a heavy use of all uppercase letters on a screen been avoided? [1]	O	O	O	
4.10	Is there a consistent icon design scheme and stylistic treatment	O	O	O	

	across the system? [1]				
4.11	Is the font easy to read? [5]	O	O	O	
4.12	If "exit" is a menu choice, does it always appear at the bottom of the list? [1]	O	O	O	
4.13	Are menu titles either centred or left justified? [1]	O	O	O	
4.14	Is the structure of data presentation consistent across the app? [1]	O	O	O	
4.15	Are system objects named consistently across the app? [1]	O	O	O	
4.16	Are user actions named consistently across the app? [1]	O	O	O	
4.17	Do abbreviations of names of stops, buses and trains follow a simple primary rule and, if necessary, a simple secondary rule for abbreviations that otherwise would be duplicates? [1]	O	O	O	
4.18	Are menu choice names consistent, both within each menu and across the app, in grammatical style and terminology? [1]	O	O	O	
4.19	Does the structure of menu choice names match their corresponding menu titles? [1]	O	O	O	
4.20	When prompts imply a necessary action, are the words in the message consistent with that action? [1]	O	O	O	
4.21	After touching items, is the system response predictable? [1]	O	O	O	
4.22	Does the app support portrait and landscape orientations? [1]	O	O	O	
4.23	Is navigation consistent across orientations? For instance, some applications use horizontal navigation in landscape and use vertical navigation in portrait.[1]	O	O	O	
4.24	Is content consistent across orientations? ("Same content" and "Keep location"). [1]	O	O	O	

5. Error prevention

Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action. If errors still happen, make sure to offer the possibility to recover from them.

#	Review Checklist	Yes	No	N/A	Comments
5.1	Are menu choices logical, distinctive, and mutually exclusive? [1]	O	O	O	
5.2	Are data inputs case-blind whenever possible? [1]	O	O	O	
5.3	Does the app warn users if they are about to make a potentially serious error? [1]	O	O	O	
5.4	Do fields in data entry screens contain default values when appropriate? [1]	O	O	O	
5.5	Are touchable areas large enough? (Target sizes should be at least 1 cm× 1 cm) [1, 5]	O	O	O	
5.6	Are targets far enough from each other? (Crowding targets) [1]	O	O	O	
5.7	If the visible part of a target is small, is there some invisible target space around it that if a user hits that space, their tap will still count? [1]	O	O	O	

6. Recognition rather than recall

Make sure that the main functions of the application are easily accessible and that their actions are intuitive. Use short menu paths for the main functions or keep the main functions visible at all times.

#	Review Checklist	Yes	No	N/A	Comments
6.1	Is remembering information dispensable and only a low level of concentration required when using the app? [1]	O	O	O	
6.2	Are all data a user needs on display at each step in a transaction sequence? [1]	O	O	O	
6.3	If users have to navigate between multiple screens, does the app use context labels, menu maps, or place markers as navigational aids? [1]	O	O	O	
6.4	After the user completes an action (or group of actions), does the feedback indicate that the next group of actions can be started? [1]	O	O	O	
6.5	Are optional data entry fields clearly marked? [1]	O	O	O	
6.6	Is the main function of the application immediately apparent? [3]	O	O	O	
6.7	Do the functions focus on doing one thing and performing only the tasks described in their names? [4]	O	O	O	
6.8	Are users able to use the app properly without having to understand the city's public transport ticketing system?	O	O	O	
6.9	Have prompts been formatted using white space, justification, and visual cues for easy scanning? [1]	O	O	O	
6.10	Are there “white” areas between informational objects for visual relaxation? [1]	O	O	O	
6.11	Is size, boldface, underlining, colour, shading, or typography used to show relative quantity or importance of different screen items? [1]	O	O	O	
6.12	Have light, bright, saturated colours been used to emphasize data and have darker, duller, and desaturated colours been used to deemphasize data? [1]	O	O	O	
6.13	Are logos or well-known abbreviations to the names of Public Transport Operators used when refering to them?	O	O	O	
6.14	On data entry screens, are dependent fields displayed only when necessary? [1]	O	O	O	
6.15	Are field labels close to fields, but separated by at least one space? [1]	O	O	O	
6.16	Is the first word of each menu choice the most important? [1]	O	O	O	

7. Flexibility and efficiency of use

The system should cater to both experienced and inexperienced users. Allow users to tailor frequent actions. Appropriately guide novice users. Make sure the user interface is scalable for different screen sizes of mobile devices.

#	Review Checklist	Yes	No	N/A	Comments
7.1	Is there any search and browse option? [1, 5]	O	O	O	
7.2	Is the searching box easily accessible? [1]	O	O	O	
7.3	Is the searching box easily recognizable? [1]	O	O	O	
7.4	Is there any advanced search option? [1]	O	O	O	
7.5	Are search results shown in a comprehensive manner to the user? [1]	O	O	O	
7.6	Is the user assisted if the search results are impossible to calculate? [1]	O	O	O	
7.7	Does the app preserve search strings between searches use autocompletion and suggestions when the user is typing? [1]	O	O	O	
7.8	Do the icons/elements used have good information scent? (i.e., icons/elements which clearly indicate where they take the users) [1]	O	O	O	
7.9	Is the app accessible to people with disabilities? [5]	O	O	O	

8. Aesthetic and Minimalist Design

The application should have simple, intuitive, easy to learn and pleasing design. The system should be free from irrelevant, unnecessary and distracting information. Graphic controls should be intuitive.

#	Review Checklist	Yes	No	N/A	Comments
8.1	Is only (and all) information essential to decision making displayed on the screen? [1]	O	O	O	
8.2	Are field labels brief, familiar, and descriptive? [1]	O	O	O	
8.3	Are prompts expressed in the affirmative, and do they use the active voice? [1]	O	O	O	
8.4	Is layout clearly designed avoiding visual noise? [1]	O	O	O	
8.5	Is the application icon recognizable enough to be found in the crowded list of applications? [1]	O	O	O	
8.6	Does the app have a simple and engaging home screen? [5]	O	O	O	
8.7	Does the app have simple and obvious registration, logging in and logging out processes? [5]	O	O	O	
8.8	Does the app use of images and multimedia content add value and/or facilitate learning? [1, 5]	O	O	O	
8.9	Are images well sized? (They should be viewed with no scrolling). Are they understandable? Is the resolution appropriate? [1]	O	O	O	
8.10	If there are videos on the app, is there a textual description of what the video is about? [1]	O	O	O	

8.11	Do clicking on the thumbnail and clicking on the video title both play the video? [1]	O	O	O	
8.12	Does the app indicate video length? [1]	O	O	O	
8.13	Does icon design have simple details? (It should not be excessively detailed) [1]	O	O	O	
8.14	Is each individual icon a harmonious member of a family of icons? [1]	O	O	O	
8.15	Does each icon stand out from its background? [1]	O	O	O	
8.16	Are all icons in a set visually and conceptually distinct? [1]	O	O	O	
8.17	Are icons labeled? [2]	O	O	O	
8.18	Are menu titles brief, yet long enough to communicate? [1]	O	O	O	

9. Help users recognize, diagnose, and recover from errors

Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution. Error messages should be written in a nonderisory tone and refrain from attributing blame to the user.

#	Review Checklist	Yes	No	N/A	Comments
9.1	If there is an input error in a form, is the textbox that needs to be changed marked? [1]	O	O	O	
9.2	Do error messages inform the user of the error's severity? [2]	O	O	O	
9.3	Do error messages indicate what action the user needs to take to correct the error? [2]	O	O	O	
9.4	Do all error messages in the app use consistent grammatical style, form, terminology and abbreviations? [2]	O	O	O	

10. Help and Documentation

The application should offer clear, direct and simply help, expressed in user's idiom, free from jargon and buzzwords; help should be easy to search, understand and apply.

#	Review Checklist	Yes	No	N/A	Comments
10.1	Are the instructions necessary for the user to get started? [1]	O	O	O	
10.2	Do the instructions follow the sequence of user actions? [1]	O	O	O	
10.3	Do the notifications, when shown, still allow the visibility of other relevant menus/functions?	O	O	O	
10.4	Is the help function visible, for example, a key labeled HELP or a special menu? [1]	O	O	O	
10.5	Is the help system interface (navigation, presentation, and conversation) consistent with the navigation, presentation, and conversation interface of the application it supports? [1]	O	O	O	
10.6	Is information easy to find? [1]	O	O	O	
10.7	Is the visual layout well designed? [1]	O	O	O	
10.8	Is the information accurate, complete, understandable and	O	O	O	

	relevant? [1]				
10.9	Is it easy to access and return from the help system? [1]	O	O	O	
10.10	If a FAQs section exists, are the selection and redaction of questions and answers correct? [1]	O	O	O	

11. Skills

The system should support, supplement, extend, or enhance the user's skills, background knowledge, and expertise ---- not replace them.

#	Review Checklist	Yes	No	N/A	Comments
11.1	Are users the initiators of actions rather than the responders? [1]	O	O	O	
11.2	Does the system correctly anticipate and prompt for the user's probable next activity? [1]	O	O	O	
11.3	Are operations easy to learn and use? [2]	O	O	O	

12. Pleasurable and Respectful Interaction with the User

The interactions with the system should enhance the quality of the user's work-life. The user should be treated with respect. The design should be aesthetically pleasing- with artistic as well as functional value.

#	Review Checklist	Yes	No	N/A	Comments
12.1	Are typing requirements kept at a minimal level? [1]	O	O	O	
12.2	Are users invited to share content and provide feedback about their experiences? [5]	O	O	O	
12.3	Can users retrieve their travel history with the app?	O	O	O	
12.4	Can users set their own sound and vibration preferences within the app?	O	O	O	
12.5	Does the default application setting make sense to the user? [1]	O	O	O	
12.6	When logging in must be done, is there an option that allows the user to see the password clearly? [1]	O	O	O	
12.7	Is it easy and clear to pay invoices through the app?	O	O	O	
12.8	Does the app allow users to email the transactions conducted through it? [1]	O	O	O	
12.9	Does the app support multiple forms of payment?	O	O	O	
12.10	Is there an option for automatic monthly invoice payment?	O	O	O	

13. Privacy

The system should help the user to protect personal or private information.

#	Review Checklist	Yes	No	N/A	Comments
13.1	Are protected areas completely inaccessible? [1]	O	O	O	
13.2	Can protected or confidential areas be accessed with certain passwords? [1]	O	O	O	
13.3	Is there information about how personal data is protected and about contents copyright? [1]	O	O	O	
13.4	If the travel history of the user is saved, can it be deleted afterwards?	O	O	O	

APPENDIX C: Usability test form

Teste de Usabilidade em contexto – Aplicação móvel *Anda*

A) Informações da/o Participante:

Nome:
_____
_____

Email:
_____
_____

Nº Telemóvel:
_____
_____

Idade: ☐ 18 a 29 ☐ 30 a 44 ☐ 45 a 59 ☐ 60 ou mais

Sexo: ☐ Feminino ☐ Masculino

Nível de experiência:

1. Há quanto tempo utiliza um *smartphone* de sistema operacional *Android*?

☐ Nunca utilizou ☐ Até 3 meses ☐ Entre 3 e 12 meses ☐ Mais de 01 ano

2. Quão bem julga conhecer o sistema *Andante* (tipos de tarifas, funcionamento das zonas, duração das viagens, etc.)?

☐ Não conheço ☐ Pouco ☐ Razoável ☐ Bem ☐ Muito bem

3. Há quanto tempo utiliza a aplicação *Anda*?

☐ Nunca utilizou ☐ Até 3 meses ☐ Entre 3 e 12 meses ☐ Mais de 01 ano

B) Tarefas:

Deve ler as tarefas em voz alta e pensar alto enquanto as resolve.
Ao final de cada tarefa deve atribuir uma classificação de 1 a 4 relativamente à inteligibilidade e à utilidade da função da aplicação utilizada durante a tarefa em causa, em que 1: Não é compreensível/ Não é útil; 2: Pouco compreensível/ Pouco útil; 3: Fácil de compreender/ Útil; 4: Muito clara ou óbvia / Muito útil ou essencial.

1. Abra a aplicação *Anda*.

Tempo (segundos)	
Inteligibilidade (1 a 4)	
Utilidade (1 a 4)	
Comentários (comentários verbais do utilizador, erros de seleção de menus, dificuldades, …)	

2. Crie um registo na aplicação.

Tempo (segundos)	
Inteligibilidade (1 a 4)	
Utilidade (1 a 4)	
Comentários (comentários verbais do utilizador, erros de seleção de menus, dificuldades, …)	

3. Inicie uma viagem na aplicação.

Tempo (segundos)	
Inteligibilidade (1 a 4)	
Utilidade (1 a 4)	
Comentários (comentários verbais do utilizador, erros de seleção de menus, dificuldades, …)	

4. Acompanhamento da viagem na aplicação.
   a) Surgem diversas estações durante a viagem. O que entende por esta informação? Acha útil?

Inteligibilidade (1 a 4)	
Utilidade (1 a 4)	
Comentários (comentários verbais do utilizador, erros de seleção de menus, dificuldades, …)	

   b) Durante a viagem, podem surgir retângulos brancos na barra superior verde com informação sobre linhas de autocarro, metro e comboios urbanos. O que entende por esta informação? Acha útil?

Inteligibilidade (1 a 4)	
Utilidade (1 a 4)	
Comentários (comentários verbais do utilizador, erros de seleção de menus, dificuldades, …)	

5. Consulte o ecrã de fiscalização (durante a viagem). O que acha do ícone? O que acha das informações apresentadas no ecrã?

Tempo (segundos)	
Inteligibilidade (1 a 4)	
Utilidade (1 a 4)	
Comentários (comentários verbais do utilizador, erros de seleção de menus, dificuldades, …)	

6. Encerramento da viagem.
   a) Após chegar ao seu destino, sair do autocarro/metro/comboio urbano e começar a afastar-se do veículo/estação, a aplicação deve encerrar a viagem automaticamente. O que acha desta funcionalidade?

Inteligibilidade (1 a 4)	
Utilidade (1 a 4)	
Comentários (comentários verbais do utilizador, erros de seleção de menus, dificuldades, …)	

   b) Lembrou-se que deve estar em outro sítio e precisa continuar a viagem, entretanto a aplicação a encerrou e já calculou seu preço. O que acha que acontece se validar novamente? (ex.: "A app começa uma nova viagem; "A app retoma a viagem anterior"; "Depende do sítio para onde vou", etc)

Comentários (comentários verbais do utilizador, erros de seleção de menus, dificuldades, …)	

7. Consulte o valor que tem a pagar pela viagem que acabou de realizar. Como interpreta esta informação? (ex.: "**1x** Título de Viagem Z2").

Tempo (segundos)	
Inteligibilidade (1 a 4)	
Utilidade (1 a 4)	
Comentários (comentários verbais do utilizador, erros de seleção de menus, dificuldades, …)	

8. Consultar o histórico de viagens na aplicação.
   a) Descreva a informação apresentada e como a percebe.

Inteligibilidade (1 a 4)	
Utilidade (1 a 4)	
Comentários (comentários verbais do utilizador, erros de seleção de menus, dificuldades, …)	

   b) Consulte as viagens realizadas durante o mês de maio de 2018.

Tempo (segundos)	
Inteligibilidade (1 a 4)	
Utilidade (1 a 4)	
Comentários (comentários verbais do utilizador, erros de seleção de menus, dificuldades, …)	

9. Consulte o ecrã de fiscalização (fora de viagem). O que acha da informação apresentada?

Tempo (segundos)	
Inteligibilidade (1 a 4)	
Utilidade (1 a 4)	
Comentários (comentários verbais do utilizador, erros de seleção de menus, dificuldades, …)	

10. Consulte seu perfil e altere a morada para “Rua Júlio Dinis, 16”.

Tempo (segundos)	
Inteligibilidade (1 a 4)	
Utilidade (1 a 4)	

Comentários (comentários verbais do utilizador, erros de seleção de menus, dificuldades, …)	

11. Altere a sua palavra-passe.

Tempo (segundos)	
Inteligibilidade (1 a 4)	
Utilidade (1 a 4)	
Comentários (comentários verbais do utilizador, erros de seleção de menus, dificuldades, …)	

12. Método de pagamento.
    a) Insira seus dados para pagamento.

Tempo (segundos)	
Inteligibilidade (1 a 4)	
Utilidade (1 a 4)	
Comentários (comentários verbais do utilizador, erros de seleção de menus, dificuldades, …)	

    b) Consulte seus dados para pagamento.

Tempo (segundos)	
Inteligibilidade (1 a 4)	
Utilidade (1 a 4)	
Comentários (comentários verbais do utilizador, erros de seleção de menus, dificuldades, …)	

13. Faça *logout* da aplicação.

Tempo (segundos)	
Inteligibilidade (1 a 4)	
Utilidade (1 a 4)	
Comentários (comentários verbais do utilizador, erros de seleção de menus, dificuldades, …)	

14. Faça *login* na aplicação utilizando os dados registados anteriormente.

Tempo (segundos)	
Inteligibilidade (1 a 4)	
Utilidade (1 a 4)	
Comentários (comentários verbais do utilizador, erros de seleção de menus, dificuldades, …)	

C) Entrevista:

1. O que achou da aplicação móvel *Anda*? Útil, com pouca utilidade? Por quê?

R:

2. O que mais gostou na aplicação?

R:

3. O que menos gostou na aplicação?

R:

4. O que achou confuso ou difícil no uso da aplicação?

R:

5. O que acha da segurança da aplicação?

R:

6. O que sugere para melhorar a aplicação?

R:

7. Que opções gostaria de ter disponíveis que a aplicação não tem?

R: