THE IMPLICATIONS OF INTERACTIVE E-PAPER TECHNOLOGY ON PUBLIC TRANSPORTATION

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Acknowledgements

This dissertation, as presented in the following pages, is the final product of a journey that started nearly two years ago with my arrival in Portugal. It is dedicated to all the people who were by my side, physically or otherwise, in this period.

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Abstract

Design is not only about form; it is just as much based on function, and the combination of these aspects intends to provide better experiences for its users. Be it everyday tasks or once-in-a-lifetime scenarios; design can make or break someone's perception towards a company, entity, product or service. Moreover, the way it manifests in those everyday activities presents countless opportunities to promote quality of life changes in trivial contact points between provider and user.

A perfect example of that dynamic is public transportation, a journey filled with steps and interactions. From planning a trip to the moment of arrival, the user needs to retrieve information regarding the itinerary, scheduled departure times, alternative lines. How and where is this information displayed when people need it? How could it be improved? Is technology the answer, and would people respond positively to it?

This study shares a glimpse into the implications of using e-paper on bus stops in the city of Porto, northern Portugal, which solutions it could bring and how users feel about that possibility. Mobility and industrial design researchers, public transportation companies and city council members will be able to use the findings of this study as a starting point to explore, understand and implement the aforementioned technology with innovative processes in user-centred solutions for the industry.

Keywords: User experience, public transportation, e-paper, timetables, real-time information, bus stop.

Resumo

O design não se baseia apenas na forma; baseia-se igualmente na função, e a combinação destes aspectos pretende proporcionar melhores experiências aos seus utilizadores. Quer se trate de tarefas diárias ou de cenários únicos; o design pode ter efeitos na percepção de alguém em relação a uma empresa, entidade, produto ou serviço. Além disso, a forma como se manifesta nessas actividades quotidianas apresenta inúmeras oportunidades para promover mudanças de qualidade de vida em pontos de contacto triviais entre fornecedor e utilizador.

Um exemplo perfeito dessa dinâmica é o transporte público, uma viagem repleta de passos e interacções. Desde o planeamento de uma viagem até ao momento da chegada, o utilizador necessita de recuperar informações sobre o itinerário, horários de partida programados, linhas alternativas. Como e onde é exibida esta informação quando as pessoas precisam dela? Como poderia ser melhorada? Será a tecnologia a resposta, e será que as pessoas responderiam positivamente a ela?

Este estudo partilha um vislumbre das implicações da utilização de papel electrónico nas paragens de autocarros na cidade do Porto, norte de Portugal, que soluções poderia trazer e como os utilizadores se sentem acerca dessa possibilidade. Os investigadores de mobilidade e design industrial, empresas de transportes públicos e membros do conselho municipal poderão utilizar os resultados deste estudo como ponto de partida para explorar, compreender e implementar a referida tecnologia com processos inovadores e em soluções centradas no utilizador.

Palavras-chave: Experiência do utilizador, transportes públicos, e-paper, horários, informação em tempo real, paragem de autocarro.

Index

Index of Tables

Index of Figures

1. Introduction

Design is much more than aesthetics, proportions, and colour schemes. It is a mindset that values problem-solving and encapsulates both form and function to enhance a project's characteristics. This approach is common to every design branch but is primarily present in product design, one of the world's most sought-out specialities.

Over the last years, we have seen a rise in user experience and interaction design as tools to improve client experience – with the expected result of increasing sales, obtaining customer loyalty, and creating new products. We frequently interact with screens in our daily lives, such as our cell phones, tablets, watches, or even our car's onboard computer. A big part of what keeps us using those devices is that they offer excellent user experience - the product's experience for the people who use it in the real world.

User experience is about how it works outside, where a person comes into contact with it (Garrett, 2011). With complex products, the user experience designs the product itself, such as a cell phone. We have to develop all its aspects, buttons, size and shape. The more complex a product is, the more difficult it becomes to identify precisely how to deliver a successful user experience (Garrett, 2011).

When it comes to user experience on public transportations, where does it stand? Transportation is a need, and when it is public, it can be accessible for everyone, everywhere, and has intensive use. Public transit helps decrease road traffic, reduce air pollutants emission, emit much less CO2 per passenger-km than a car, and are safer. Regarding technology, general trends such as The Internet of Things (IoT), mobile devices, and open source can significantly influence transportation and provide a context in which public transportation agencies operate (OPTP, 2017).

According to Oregon Public Transportation Plan (2017), a significant hurdle for many potential public transportation riders is accessing easy-to-understand bus schedules and routes. Technologies to address this challenge are increasing rapidly and are ever more available on mobile devices. Nevertheless, how to give easy and accurate access to on-time bus and subway schedules and routes for people who do not have access to the internet or do not always carry a mobile device with them? How to provide this information in an easy and accessible way?

It is crucial to keep the user's needs in focus, and for that, a methodology of qualitative and quantitative interviews, focus groups, and A/B tests are essential. A human-centred design approach for this project is necessary because it puts human needs, capabilities, and behaviour first, then designs to accommodate those needs, capabilities, and ways of behaving (Norman, 2013).

This research aims to improve user experience on public transportation itineraries through e-paper technology in an innovative process using Design Thinking.

2. Literature review

2.1. Introduction

A literature review is a comprehensive summary of the ideas, issues, approaches and research findings that have been published on a particular subject area or topic. (Kiteley & & Stogdon, 2013)). A helpful literature review will aim to weigh the contribution that specific ideas, positions or approaches have made to the topic (Hart, 1998). This literature review is a preparation for empirical research, identifying a clear research gap, which will form the ultimate research topic.

The literature review's essential evaluation clearly distinguishes opinions, theories, and empirical facts (Levy & Ellis, 2006). After investigating 13 articles, in the manner mentioned above, it became clear that there are not many studies investigating the use of e-paper technology on public transportation focused on the user experience. There are many recent studies where we can evaluate the public transit user's behaviour. Some suggest using the research to be applied when developing a new service in the urban transportation sector for future services providers to enhance its clients' user experience. Several authors also used the mobile device as the leading technology to be offered as the field of study, relying on the user to have the tool to perform the study's object. These studies' location was also one of the gears to conduct future research, meaning that none was researched for a Portuguese public transit context. The papers crucial for this research were grouped into two topics: Enhancing User Experience on a Public Transportation Context and Smart Public Transportation Information System, as table xx illustrates.

Table 1 - Literature Review Approach

Literature Review	
Query used in *Scopus:* TITLE-ABS-KEY ("electronic paper" OR "epaper" AND "transportation" OR "public transportation")	
Topics and Authors	
Enhancing User Experience on a Public Transportation Context	Smart Public Transportation Information System

Topics and Authors	
Hildén, Väänänen, & Syrman (2018)	Scott et al. (2014)
Kamilakis, M., Gavalas, D., & Zaroliagis, C. (2016)	Ekşioğlu, M. (2016)
Hildén, E., & Väänänen, K. (2019)	Wirtz, S., & Jakobs, E.-M. (2013)
Lin, T. S., & Chang, C.-N. (2015)	Foth, M., & Schroeter, R. (2010)
Hildén, E., Väänänen, K., & Chistov, P. (2018).	Gustarini, M. et al. (2014)
	Yu, J., Shi, A. Q., Zhang, Y., & Han, C. J. (2013)

2.2. Enhancing User Experience on a Public Transportation Context

In research from dell'Olio et al. (2011), public transport users' desired quality is different from the perceived quality because it does not represent the users' daily experiences, but instead what they want, hope for, or expect from their public transport system. The study of the desired quality is crucial, which gives local authorities the background information for personalised marketing policies based on the user's requirements rather than their daily perceptions. The variables that users value most in public transport are waiting time, cleanliness and comfort. But the degree to which they are valued varies according to user category. This discovery is interesting because it allows future research to dig deeper into some of these public transport users' pain points. Thus, Hildén et al (2018) developed the Bus Travel Experience Model that visualises and concretises the building blocks of passengers' travel experience. The model emphasises the significance of digital services in the broader service context of public transportation. Hildén & Väänänen (2019) continue their research to help service providers better understand their users and in (Hildén et al, 2019), the study was based on a bus specific context. Other studies such as (Wirtz & Jakobs, 2013) and (Gustarini et al, 2013) focus on user experience by only providing information on mobile applications.

2.3. Smart Public Transportation Information System

Boshita et al. (2019) describe an intelligent bus stop design that can use responsive web design and display optimised content on e-paper with different specifications with one source performing with a prototype. There are many cases in which the visibility of information drops significantly depending on the amount of knowledge of the content displayed at the bus stop and the display device's specification to be adopted. The paper describes how the prototypes function and how their performance is evaluated only by the processing time. The results of the prototype itself are very intriguing. Still, the study lacks an understanding of how the bus transport users will accept this new type of product, evaluating the experience and interface. Many technologies are being analysed in recent years to enhance the user experience and help reduce the environmental impact and be a cost-effective alternative. That is what Scott et al. (2014) suggests, investigating the potential use of e-paper technology as an alternative to existing information provision at transportation locations in Birmingham, UK. This intelligent information system provides the platform for delivering more comprehensive real-time information and additional planned service or general transport information. Moreover, it can be an integral part of a holistic approach to providing comprehensive information utilising various outlets. It can take full advantage of the growth in technology and the use of smart devices (Scott et al., 2014, p. 4). The methodology used to evaluate users' prototype on this research was only a survey with 150 customers not having qualitative feedback on the overall solution.

2.4. Conclusion

A gap in the literature was achievable after following the literature review's synthesis and analysis. Therefore, there is a lack of research investigating e-paper technology usage on public transport information systems using a mixed methodology approach, with surveys, focus groups, user evaluation and interface evaluation.

3. Methodology

3.1. Research Questions

The literature review evaluation enabled us to perceive many literature gaps regarding enhancing user experience in a public transportation context. When wanting to analyse the e-paper technology used on smart public transportation information systems, essential questions come:

- **(Q1)** What would an e-paper public transportation information system experience and interface look like in the context of the Porto public transportation system?

- **(Q2)** How will public transportation users perceive this technology?

- **(Q3)** Which information is essential and how to design this solution?

The present research is defined as its primary objective: to design a solution for presenting timetables at the public transit using the e-paper technology. The Design Thinking framework was applied to develop a solution that will enhance the user experience. The Design Thinking framework, according to Gibbons (2016), is a user-centric approach to problem solving can lead to innovation, and innovation can lead to differentiation and a competitive advantage.

As previously identified in the Literature Review, there is a shortage of understanding the implications of interactive e-paper technology on public transit, especially from the user perspective, approaching their behaviour, pain points, and expectations. This research gap using the design thinking approach helps the problem characterisation from a human-centric perspective.

3.1. Research Design

Research designs are plans and procedures for research that span the decisions from broad assumptions to detailed data collection methods and analysis. The selection of a research design is also based on the nature of the research problem or issue being addressed, the researcher's personal experiences, and the audiences for the study (Creswell & Creswell, 2018). A mixed methods research will validate the assumptions made by overviewing the three research questions.

Mixed methods research is an approach to inquiry that combines or associates both qualitative and quantitative forms. It involves using qualitative and quantitative techniques and the mixing of both approaches in a study. Thus, it is more than simply collecting and analysing both kinds of data; it also involves using both approaches in tandem so that the overall strength of a study is more significant than either qualitative or quantitative research (Creswell & Clark, 2007). The reason for choosing the mixed methods is to expand on the findings of one method (quantitative) with another (qualitative). According to Creswell & Creswell (2018), mixed methods design is helpful when either the quantitative or qualitative approach is inadequate to understand a research problem, or the strengths of quantitative and qualitative research can provide the best understanding.

3.2. Design Thinking Method

According to Interaction Design Foundation (2019), design thinking is a non-linear, iterative process that teams use to understand users - who they are and what they need - challenge assumptions, redefine problems and create innovative solutions to prototype and test. This framework encompasses five phases: empathise, define, ideate, prototype, and test, represented by Figure 1.

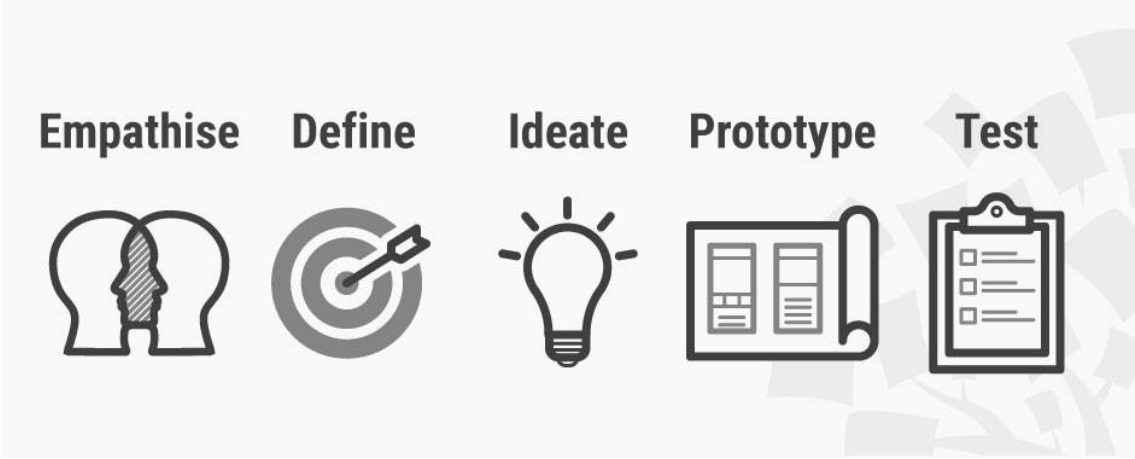


Figure 1 - Design Thinking (IDF, 2019)

The empathise phase is to better understand the users, who they are, their needs, pain points, and primary goals. This phase will also give a better characterisation of the research problem. The usage of research design and tools is crucial to develop that understanding.

According to Garrett (2010), research tools - such as surveys, interviews, or focus groups - are best suited for gathering information about the general attitudes and perceptions of the users. After the data collection at the Empathise phase comes the definition of the core problems, with the Define Phase. According to the Interaction Design Foundation (2019), the Define stage also allows gathering ideas to establish features, functions, and any other elements that will enable them to solve the problems.

The third phase of design thinking is for generating ideas with all the reliable information gathered in the previous stages. The Ideate phase will identify potential solutions with techniques that simulate free and creative thinking. The end of this phase is finding the best way to either solve a problem or provide the elements required to circumvent it (Interaction Design Foundation, 2019).

The fourth and fifth phases are for prototyping and evaluation of the solution generated by the Ideate stage. According to the Interaction Design Foundation (2019), Prototyping is an experimental phase aiming to identify the best possible solution for each of the problems identified during the first three stages. The potential solutions can be improved, re-examined, or rejected, always focusing on the user experience. The Evaluation phase, which is the final stage, will be for user evaluation with potential users, understanding specific aspects of user behaviour, and interaction with the final solution. The results may indicate that, if needed, there will be some adjustments, needing to come back to the other stages, making alterations or refinements. This methodology approach is an iterative process, enabling innovation and creates an outcome with excellence.

3.3. PACT Analysis

The PACT analysis is a human-centred design approach for human-computer interaction that puts people at the design process centre. Sometimes, even the human-centred approach may have a blinded eye because they sometimes forget that they are not users. According to (Budiu, 2017) designers need to create systems that are right for those who will use them. Benyon (2013) conceptualises the design process as involving much iteration and exploration of what the system is meant to do and the qualities it should have. The PACT analysis is a helpful framework to investigate the first stage of the design thinking process. Each element of this analysis supports developing an effective interactive system that supports the user's needs.

3.3.1. People

People use technologies to undertake activities in contexts. If the technology is changed, then the activities' nature will also change (Benyon, 2013). Public transport represents a means by which people can efficiently move throughout a region with the most negligible impact on the environment because it eases congestion and reduces emissions. There could be many reasons people use public transportation: economic, social, or/and environmental causes.

People are the first subject of the analysis, and they need to be evaluated by their physical, psychological, and social differences. Humans differ in many ways, and a human-centred design approach needs to develop technological solutions that encompass people with different abilities. For example, people with disabilities need to consider the public transportation system's overall experience. Variability in the five senses - sight, hearing, touch, smell, and taste - significantly affects how accessible, usable, and enjoyable using technology will be for people in different contexts (Benyon, 2013). In Portugal, about 16% of the population between 15 and 64 years old (about one million people) have health problems that make it challenging to perform the most basic routine activities, according to the study "Health and Disability in Portugal," by the National Institute of Statistics (2012).

As for social differences, people have different goals in using systems, products, or services. Some may need to go to work every day or go to school; others may need only occasionally. According to recent research from Instituto Nacional de Estatística (2018), Portugal's main metropolitan areas - Lisbon and Porto - residents' public transportation usage comes in third place, losing to cars and motorcycles and bicycles. The study has shown that the main reason that people choose other transit modes - being cars the most - is due to the lack of "speed" and "comfort" of public transport (for half or more of the respondents). They were followed by "public transport network without direct connection to the destination," "lack of alternative," and "public transport services without the necessary frequency or reliability" (with values above 25%). The quantitative research will reveal more information about the user and its needs.

3.3.2. Activities

Activities can be evaluated for their complexity (few steps or many), the frequency - continuous or interruptible - cooperative features, and the content, with what information and media are needed to do the activity (Benyon, 2013). Public transportation has a vital role in the quality of the inhabitants of a city. According to Preston, public transport can be defined as any form of transport available for the general public (2020). Public transport encompasses bus, coach, rail, metro, domestic air, and taxi modes. It exists to improve environmental quality, increase accessibility for all, and improve economic efficiency (Ferreira & Lake, 2002).

The goal for people using the public transit system is to quickly go from one place to another inside the perimeters of a city or metropolitan area. It is an activity that depends on the person's necessity, and it can be used frequently (weekdays), every other day, or rarely. The activity also depends on transportation mode, and the data needed for people to act is information about the route and the timetables. According to the National Institute of Statistics (2012), in Portugal, the three main reasons for people to use public transportation are the following: they do not drive/do not have a car, do not have other alternatives, and it is a cheap option. The primary purpose of the journeys was to go and come back from work.

3.3.3. Context

For activities to happen, they need context, so they need to be analysed one after the other. There are three types of context distinguishable from one another - the organisational context, the social context, and the physical circumstances under which it occurs (Benyon, 2013). Transport is a critical factor in social inclusion. It provides the ability of an individual, family, or community to access economic and employment opportunities.

Public transport in major metropolitan cities can be the fastest, safest, and cheapest way to connect to work, family, and social activities - facilitating social inclusion and providing an additional opportunity (Tourism & Transport Forum Position Paper, 2012). When talking about transportation only, Portugal has 88% of the population using a car, being the second largest population in Europe that most use the vehicle as a form of mobility, losing only to Lithuania (Eurostat, 2020).

Inside the metropolitan areas of two of the largest cities in Portugal - Lisbon and Porto - after cars and walking on foot - the bus is the most employed, followed by metro and railways (National Institute of Statistics 2012). The physical environment that supports public transit depends on what transportation mode people are using. When talking about the bus experience, we have the bus stop, with the minimal physical evidence being a pole-mounted flag with a suitable name/number of the bus stop. Some stops are a shelter made of steel and glass with inbuilt seats. It may feature advertising from simple posters to illuminated, changeable displays. Information on the stops is about routes, timetables, frequency, and telephone numbers to relevant travel information services. As for a metro station or railway station's physical circumstances, it has to provide a means for passengers to purchase tickets, board trains, and relocate the system in an emergency. At the entrance, it features the name with the station's logo, a place to buy tickets, and information on lines and changing routes. The station is divided into an unpaid zone connected to the entrance and a paid area related to the train platforms. For people with disabilities, an elevator is available, taking people from the unpaid level to the platforms. There are emergency doors and alarm systems installed and maintained in case of emergencies. Information on the following vehicles are provided by LED or LCD screens and recorded train announcements at the platform level.

The social setting is essential for the use of public transit. Public transportation exists in urban areas for all people to have access to mobility cost-effectively. So they try to be accessible for people with different social skills, status, and conditions. It happens with crowds going to different places, and people can do it alone or in the company of others. In an organisational context, information is essential to keeping a well-integrated system of large scale in operation hours, personnel, routing, location of stations/stops, interval, and level of congestion (Shibayama, 2017, p. 3680).

3.3.4. Technology

Interactive systems can apply technology by inputting data, transforming it according to the system in some output data. Typically consists of hardware and software components with people using these systems engaging in interactions (Benyon, 2013). The technology analysed by this framework is e-paper technology. According to GDS (2017), e-paper displays contain millions of miniature capsules filled with a clear fluid containing microscopic particles of different colours and electrical charges. Figure 2 illustrates the electrodes located above and below the tablets move up and down when a positive or negative electric field is applied, making the electronic paper display's surface reflect a specific colour.

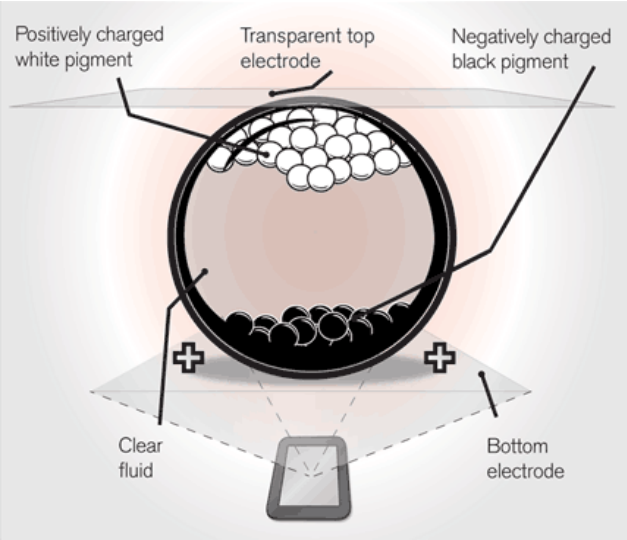


Figure 2 - E-Paper Capsules (GDS, 2019)

E-paper is highly visible outdoors and consumes power only when updating display content. Therefore, the power saving effect is exceptionally high, as it is possible to operate only with solar power generation (Boshita et al., 2019). This technology has many benefits when applied to an urban ecosystem: e-paper is more comfortable to read outdoors and in bright sunlight; therefore, it is perfect for all indoor and outdoor displays, such as traffic signs, retail shelf labels, interactive museum signs, and passenger information boards, as Figure 3 demonstrates. (GDS, 2017).

Figure 3 - E-ink Outdoor Sign (Richter, 2021)

The use of e-paper technology to provide information on public transportation allows timetables to be updated and changed when required, with updates made to the on-street units within minutes of the service registrations going live (Scott et al., 2014). Input data of vehicles would be transmitted by a location system going to a cloud-based content system transforming the output data into an image file (Boshita et al., 2019). Assumptions on the content would be live timetables, expected journey times, destination arrival times, days of alternative information, news, and general public information. Some research will be necessary to confirm these assumptions, especially on the user's needs, goals, and pain points. The research design is described in the next session.

3.4. Data Collection

3.3.4. Survey

To measure user behaviour, understand who they are and what they need, a survey in the form of a questionnaire was applied. The targeted group was people who frequently use public transportation in the Porto area. The questionnaire took place on Google Forms, and the author selected the sample from the University of Porto contacts. The email with the questionnaire link was sent to 9008 contacts and got 301 responses. Questions were a mix of open-ended and closed-ended inquiries. The complete questions of the questionnaire are included in the Appendix A of this document.

3.3.2. Discussion of Results

The characteristics of the sample collected from the University of Porto show a broader range of age between 18 to 31 years old and a small range of respondents from 41 to 60. Most of them (89%) use public transportation, primarily by buses and metro. The questionnaire results indicate that the respondents learn about timetables mainly by mobile applications, websites, and bus stops. The complete answers of the questionnaire are included in the Appendix B of this document.

When asked about e-paper technology, 70% were familiar with it. However, only 40% had ever interacted with this technology in the form of a product: e-books, e-ink tablets, commercial display products, and digital signage in meeting rooms. The questionnaire also allowed the author to know if the respondents enjoyed this technology, and surprisingly 97,5% said they enjoy the experience that e-ink provides.

The most important result of the quantitative research was to know the opinion of e-paper technology combined with a solution for timetables for public transit. When presented with a picture of the Transport for London, as Figure 3 illustrates, using the e-paper technology for interactive bus stops, the subjects graded to be just a little innovative but very beneficial and helpful, which was a pivotal answer to move along with the research questions.

Figure 4 - Interactive E-paper Bus Stop in London (Transport for London, 2020)

The respondents also were asked about what sets of preliminary information the interactive e-paper stop would have. Interaction with a piece of physical evidence such as buttons is valuable. Some secondary information like last-minute news, weather information, and points of interest could enhance the experience.

The quantitative research allowed validating the initial hypothesis on how beneficial the interactive e-paper technology on public transportation could be, confirming the interest of its users. As for the bus being the second most used type of public transportation, it could also be the one to have more benefits in implementing this type of solution. The next chapter will delineate the problem better to generate ideas, ending with a more human-centred design solution.

4. Problem Characterisation

4.1. Introduction

After exploring the user, the public transit activity and context, and the e-paper technology, the proposed dissertation's problem statement can be defined. This stage is valuable because it addresses potential conflicts and rough spots in the product while the whole thing is still hypothetical. We can identify what we can tackle now and what will have to wait until later. Having identified requirements provides a framework for evaluating ideas as they come along, helping to understand if they fit into what the project is already committed to building (Garrett, 2010).

Studying the implications of using e-paper technology for interactive public transit information is innovative because there are only a few studies from a human-centric perspective utilising the design thinking framework. Recent studies are focused on an outcome with no focus on the user experience, solely on the engineering perspective.

4.2. Porto Public Bus Network

The city of Porto has an extensive public transit system operated by the Sociedade de Transportes Colectivos do Porto (STCP), which includes the metro, buses, and trams. With a network extension of 492 km, 73 bus lines (including streetcars), 2 484 bus stops, and 75 985 million passengers (STCP, 2019). STCP provides a modern fleet of 425 buses, with an average age of six and a half, as is shown by Table 1.

Table 2 - STCP 2019 Report

Category	**Data**
Network Extension	492 km
Bus lines	73 lines
Bus Stops	2 484 stops
Passengers	75 985 million
Fleet	425 buses

STCP's fleet of both single and double-decker buses and articulated buses are generally white with a blue roof and a blue and green stripe along the sides. Some lines are under concession to private companies. STCP operates one of the largest gas bus fleets in Europe, with 255 vehicles, representing about 50% of its fleet. The main bus terminals in Porto 's Metropolitan Area are the Campo 24 de Agosto Bus Terminal and the Parque das Camélias Bus Terminal.

STCP operates in 33 boroughs of six municipalities of the Porto Metropolitan Area (AMP): Porto, Gondomar, Maia, Matosinhos, Valongo and Vila Nova de Gaia with 73 lines. The Andante card is a system that allows the passenger to have access through buses and metros by using the same card. The Andante card provides two types of cards: the blue card and the silver card. The simplest ticket is the blue card, which the passenger can pay by the journey. The type of journey is defined by which zone his final destination is found. Figure 5 shows the zones covered by the Andante card. The type of zone establishes the ticket cost and the titles that allow travelling at a particular time, according to the areas they include (Metro do Porto, 2020).

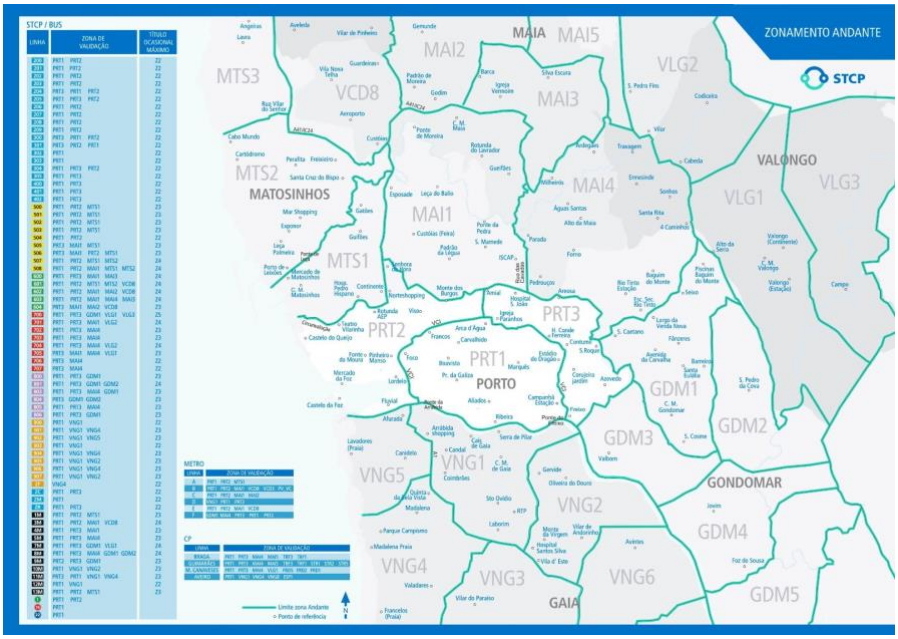


Figure 5 - STCP Andante Zoning (STCP, 2019)

The Andante Silver card illustrated in Figure 5 is mainly used for monthly passes. It is valid for the zones chosen by the passenger, allowing them to travel in those areas for a month. The areas of the zones provided by the Andante Card are slightly different. There are 11 zones in Andante Gold (C1, C2, S11, etc.), with the centre (C1) selected by default. The monthly prices depend on what Andante zones the passenger chooses.

Figure 6 - Andante Cards (Metro do Porto, 2020)

The physical evidence of the Porto Metropolitan Area (AMP) bus stops are standardised by two types: the shelter made of steel and glass with inbuilt seats and advertising; and the pole-mounted flag with a suitable name/number of the stop. As figure 7 shows, the first one has more space to provide information, such as Porto's bus network, with all the routes and bus stop names.

Figure 7 - Shelter Bus Stop at Porto (Transportes Online, 2020)

The pole with the mountain flag is the most common bus stop, easily implemented throughout the network. As Figure 8 indicates, the number and name are seen at the top, enabling the passenger to see such information from a distance.

Figure 8 - Bus Stop Pole Information (From the Author, 2021)

Then, when the passenger comes closer, another sign with information is located near the centre of the pole, a paper preserved by an aluminium structure with transparent acrylic. The information it shows is the bus times (business days, summer, weekends), itineraries, zones, real-time data provided by a QR Code, help and other contacts, as Figure 9 demonstrates.

Figure 9 - Bus Stop Pole Information II (From the Author, 2021)

This evaluation of current bus stops provided by Porto's public transit is essential to identify and focus on specific issues of the existing interface, allowing the solution to be a better version of what already exists but being consistent with the branding guidelines STCP current visual elements. The goal is that the user has a better experience with the new solution. However, it is also crucial to remain familiar with the branding and visual guidelines that the STCP already presents.

4.3. Real-Time Information System

Real-time information systems give passengers estimated arrival times for diverse public transport modes across platforms. The data can be delivered in varied forms, including via information screens at stops or stations, transport operators' websites, text message alert services, or third-party apps (What Works Growth, 2017). The majority of real-time information relies on automatic vehicle location (AVL) and Global Positioning Systems (GPS) to estimate arrival times for passengers and transit system operators. The usage of real-time technology can benefit agencies by improving safety and security, providing a better experience to passengers, and increasing customer satisfaction. Figure 10 demonstrates how the flow of the real-time information system works in messaging signs at stops and mobile

technology by the location coordinates that feed a public server and inquiry to the navigation server.

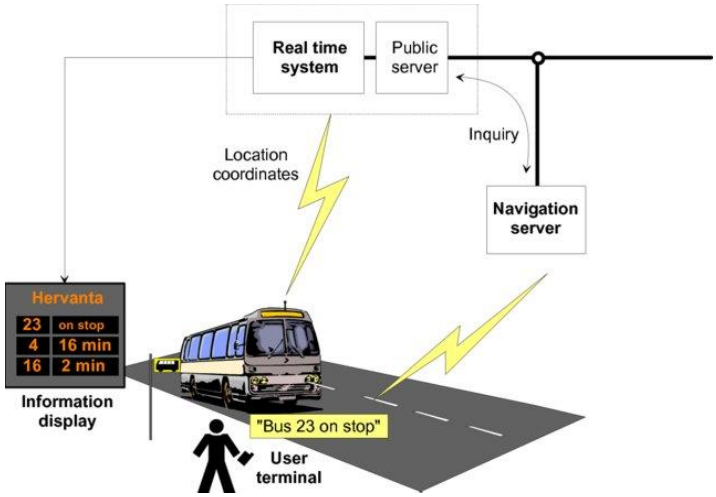


Figure 10 - Real-time information flow (Koskinen & Virtanen, 2004)

Features like mobile technology can disseminate Real-time information, dynamic messaging signs at stops, onboard annunciators and combine real-time vehicle location data with onboard automated fare collection (AFC) and automated passenger counter data to provide an estimate of how crowded a bus or train is (Karlen, 2017).

Building a proprietary system to provide real-time information can be risky, so most transit agencies work with vendors or produce data using established standards.

4.4. The General Transit Feed Specification

The General Transit Feed Specification (GTFS) is a standard format for public transport, split into a static component that contains schedule, fare, geographic transit information, and a real-time element that contains arrival predictions, vehicle positions, and service advisories (GTFS, 2021). According to Bruglieri et al. (2015), the GTFS format allows public transport managers to publish through the so-called feeds and updated information in a shared structure. Each feed comprises several text files describing detailed info like the stops associated with each line, the routes, the timetables compressed by a ZIP file, illustrated by Figure 11.

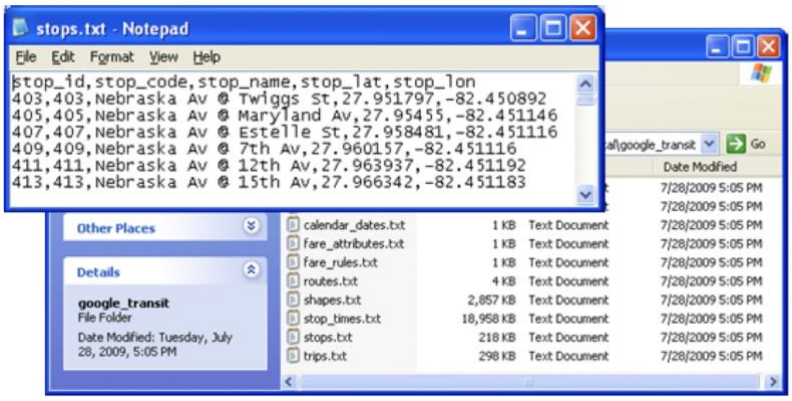


Figure 11 - GTFS dataset (Barbeau & Antrim, 2013)

As stated by GTFS (2021), many types of applications can rely on the use of GTFS data:

- Trip planning and maps support planning journeys from one location to another using public transit and other forms.
- Designing in a timetable format a printed list of the agency's schedule.
- The assisting of transit riders with disabilities.
- Applications that assist transit professionals in assessing the current or planned transit network, including ridership forecasting.
- Real-time transit information – applications that use GTFS data along with a real-time information root to provide estimated arrival information to transit passengers
- Public Information Displays - electronic displays to show schedule information, service advisories, real-time arrivals or other information.

Before transit agencies can benefit from these applications, they must create and disseminate their data in the GTFS format. First, agencies should understand the GTFS format and determine how their data will fit into this format. Second, transit agencies must choose between formatting a GTFS dataset in-house or outsourcing the task (Bruglieri et al., 2015).

5. Ideation and Prototyping

5.1. Introduction

The current chapter presents and discusses generating ideas of an interface for an interactive bus stop with the technological approach of e-paper technology. The PACT analysis demonstrated more about the technical bits of the e-paper, that are available in chapter three if any details need to be remembered. The main focus of this chapter is to present solutions, analyse the blueprint of the service, to select further down an interface design to prototype. Interface design is all about choosing the correct interface elements for the task the user is trying to accomplish and arranging them on the screen in a way that will be readily understood and easily used (Garrett, 2010). The next chapter will be an evaluation of the interface with real users.

5.2. Generation of Ideas

According to Benyon (2013), many techniques can help develop an understanding of the design problem and envision possible solutions. Envisionment is fundamental to effective human-centred design, enabling us to see things from other people's perspectives. To help set the ideas in a more accessible way, the method for generating ideas was through hand sketches. Sketches enable divergent thinking, a technique that is key to generating a wide range of ideas. With sketches, ideas and thoughts can be quickly visualised and explored (Benyon, 2013). Based on research from the discovery phase of this thesis, real-time information on bus arrivals, timetables, names of stops and information on routes are the most important. Based on these learnings, the generating of ideas is based on the screen size of a 13.3" single screen, switching the interface to secondary information by the usage of buttons, as Figure 12 shows some ideas using this screen size.

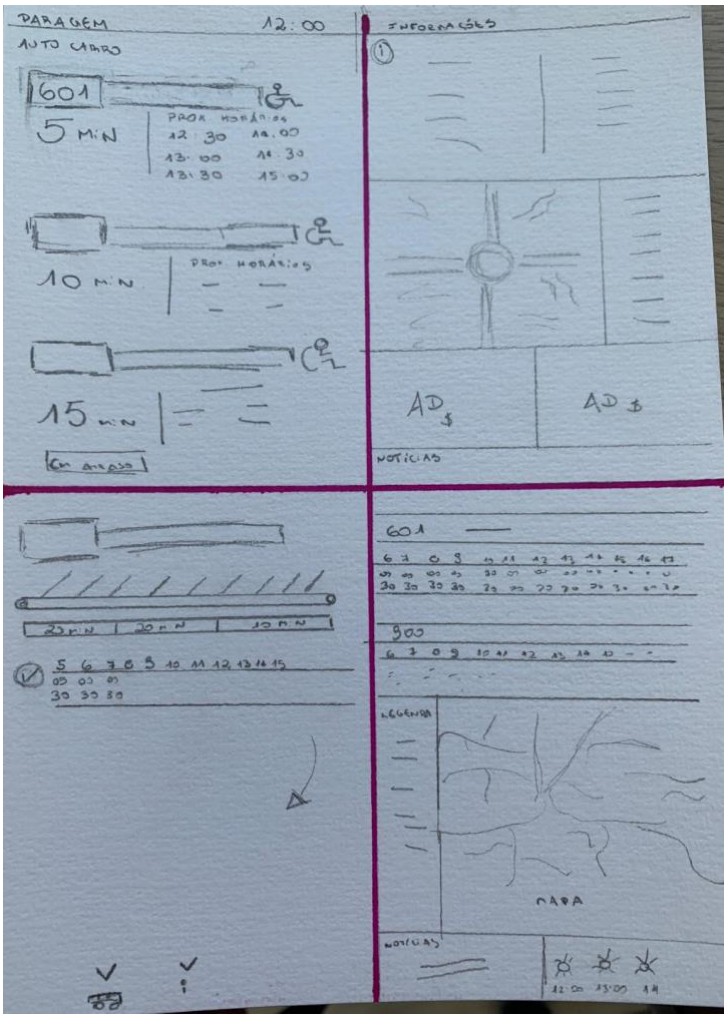


Figure 12 - First Sketches (From the author, 2021)

The generation of ideas came from some hypotheses based on research from previous chapters, emphasising the learnings from the questionnaire. Some of these hypotheses are:

- The essential information needs to be visually impactful so that the user can see from some distance. As the user gets closer to the display, it can see more detailed information.
- Estimation on arrival is essential information for the display, as seen in the responses by the questionnaire.
- Icons are essential to inform if the bus arriving is accessible for people with disabilities.
- Other arrival times can be displayed next to the real-time information as well as warnings for delayed buses.

- Names of stops and bus itinerary are essential to be displayed. Real-time information may help predict how long the travelling will be, estimating arrival times on the most important bus stops.
- Interaction with a button is of interest by the users, so secondary information such as nearby places, points of interest, latest news and weather conditions may be displayed.
- The users do not appreciate Ads, but their implementation may be of interest by the transport operator, which can monetise and help pay the costs of implementing the interactive e-paper bus stop.

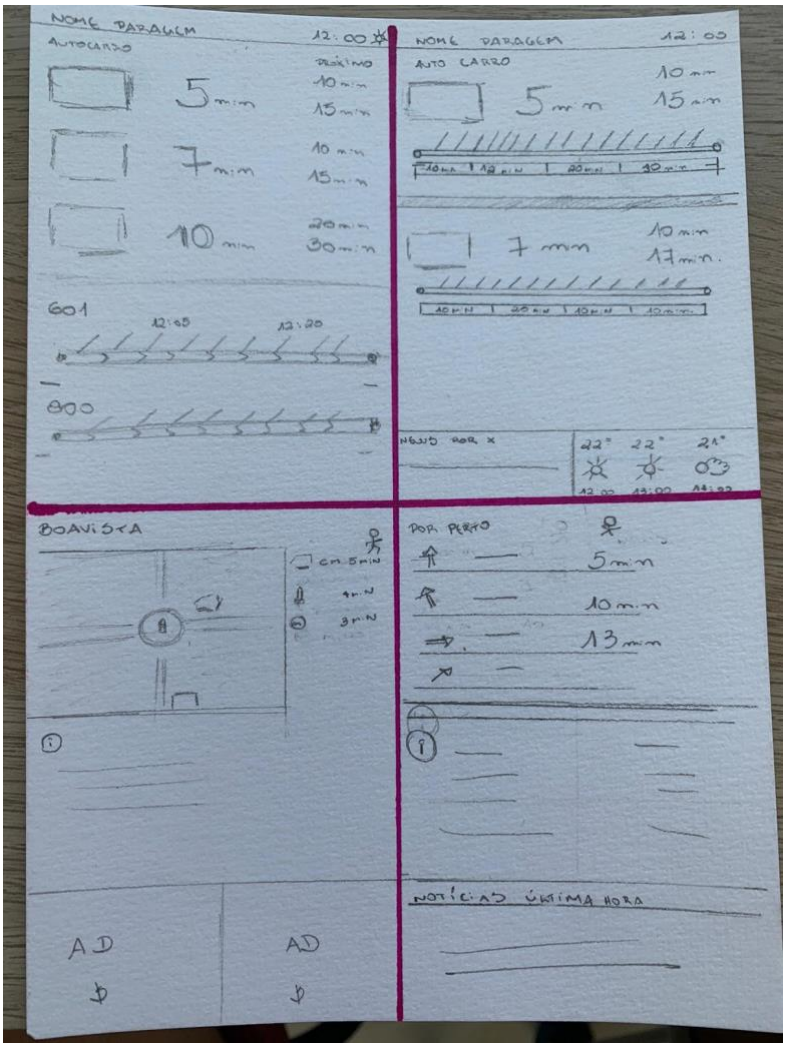


Figure 13 - Second Sketches (From the author, 2021)

Figure 13 demonstrates the effort of trying to translate this hypothesis into structured interfaces, with ideas flowing in a wide range of different solutions. The must-have data with real-time information is always prioritised, with the numbers on arrival times sized to be seen at a glance. This generating of ideas by the hand sketching method is solely for the interface of the e-paper bus stop. The physical evidence, with the casing and buttons, will be better described later.

5.3. Wireframing

For as long as people have had information to convey, they have had to make choices about how they structure that information so other people can understand it and use it (Garret, 2011). The information displayed on the screen is first categorised by the user's needs: real-time arrival information, routes and itineraries. As pointed out by the users' interest in having a button to bring more interaction to the solution, secondary data is grouped to be displayed on the second screen, allowing the focus to be on the passengers' immediate needs: arrival times, bus routes, stops and ticketing zones.

After generating ideas, the best ones are structured by a wireframe. According to Bowles and Box (2010), a wireframe is a low-detail representation of an interface, providing a simple inventory of what will be displayed and how it should be laid out. A wireframe is a deliverable that addresses the organisation of information, content, and functionality. Wireframes are beneficial because they integrate all three elements of the structure plane: interface design, within the design and selection of interface components; navigation design, through the identification and definition of core navigational systems; and information design, the placement and prioritisation of informational elements (Garrett, J. J. 2010). For this project, the wireframe will be essential to confirm that the final product will meet the user's needs.

Figure 14 - Wireframes (From the Author, 2021)

Figure 14 shows the wireframe that the interactive e-paper stop will display more often:

- Information on the bus stop name, date and time.
- Bus line number and destination are displayed, and the real-time information on the bus arrival, visually impactful. The bus lines shown are prioritised by the arrival time in a crescent order. An icon next to the time indicates if the bus arriving is accessible for people with disabilities.

- Below the arrival information, the interface has a component that identifies the route, enabling the passenger to see the bus stops names throughout the journey.
- Real-time information helps estimate arrival times, so they are displayed at the bus stops along the route.
- Below the route information, an additional element helps the passenger visualise the Andante zone through the journey.
- The interface is organised to display three bus lines at a time, so if the stop has more than that, the display navigates itself, changing the information displayed to show real-time information on all the lines that the bus stop provides.
- The information on the foot of the interface gives information about the STCP's Linha Azul, with working times, phone and email if the institution needs to be contacted.
- Also, for more timetables that are not provided in real-time, a QR Code contains the complete information on the timetable of the indicated lines. The QR Code contains the URL for the STCP's full schedules of the lines supported by the stated bus stop.
- Lastly, weather information, with temperature, icons indicating if the next five hours will be sunny, cloudy or rainy, are at the bottom of the display.

Figure 15 - Second Wireframe (From the Author, 2021)

For the user to perform the interaction between screens, a button will provide the change in the elements of interface information, as seen in Figure 15:

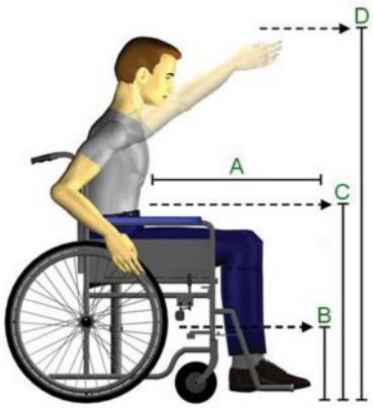
- The other screen will help the passenger visualise Porto's city bus network from a range of the stop, allowing him to perform any interchanges of routes, metro and train stations, or even be informed of the sights to see in the area.
- To help with the monetisation of these digital e-stops, spaces for publicity will be available for purchasing or leasing.

- Partnerships with Portugal's news networks may also help fund the costs of implementing the e-stops, where space for last-minute news is also available and highly demanded by the questionnaire subjects.

5.4. Accessibility

When designing a solution, it is essential to understand that many users will be experiencing it in different ways. Accessibility in public environments is crucial. If all segments of the public are to have access to social services, accessibility is a prerequisite. Ergonomics-wise, the pole and height of the casing need to be discussed to be accessible for people in wheelchairs.

In research from Tilley and Henry Dreyfuss Associates (2001), For a common-sized wheelchair, the seat height is 18-22", and the overall width is 22.5-27.0". These values can help design furniture, adjust work surface heights, and accommodate access for wheelchair users. For reaching the button of the interactive e-stop, the maximum height between the floor and the button should be 1,20 cm (48"), as Figure 16 indicates.



Measurement	Letter	Value
Desk Depth	A	20″ – 25″
Lower Reach Height (minimum)	B	9″
Desk Height	C	27″ – 34″
Shelf Height (maximum)	D	48″

Figure 16 - Guidelines for wheelchair users sitting at a surface (Allsteel, 2006)

The universal guidelines for electronic displays, according to Tilley and Henry Dreyfuss Associates (2001), the display screen should be perpendicular to the normal sightline, or no greater than a 30° off-axis. Brightness and contrast to the background should be as high as possible. The e-paper technology provides a high-brightness, high-contrast switchable element. It is more comfortable to read, providing a wider viewing angle than most light-emitting displays.

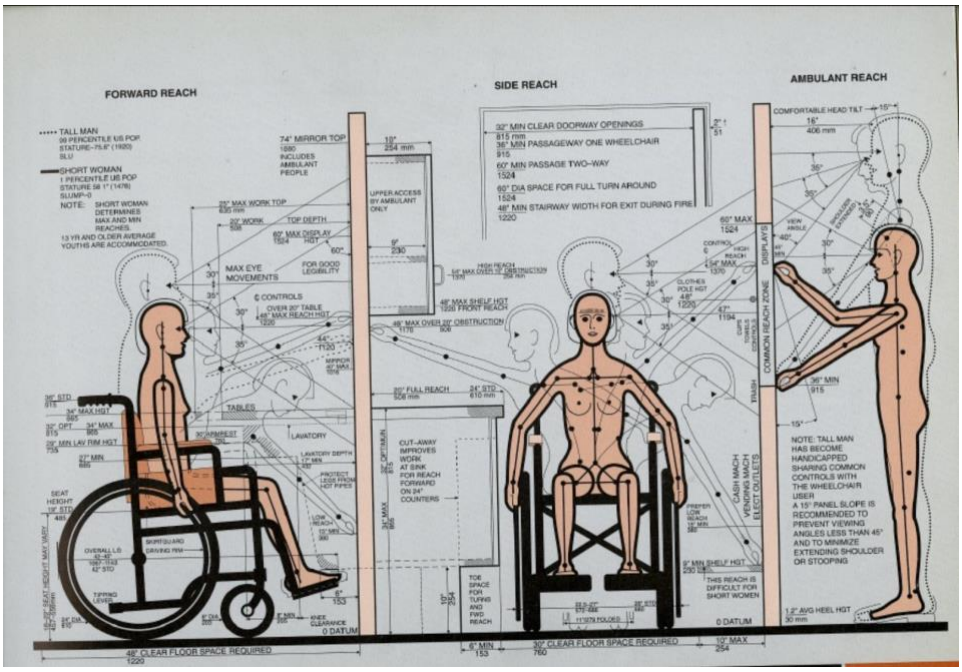


Figure 17 - Reach factors for the differently-abled (Tilley and Henry Dreyfuss Associates, 2001).

Figure 17 illustrates the reach factors for the differently-abled, where we can see the standard reach zones of displays. The study by Tilley and Henry Dreyfuss Associates (2001) demonstrates the prospects from different heights and abilities. This study helps delimit the height from the floor to the buttons and the height of the casing.

5.5. Physical Space

The solution of an interactive e-paper is a blended solution that mixes the physical with the digital space. One of the goals of this solution is to enhance the user experience on public transportation. The shape and content of the physical space are as important as the digital space, and how they are brought together is crucial for the flow of the experience. This mix of physical and digital is called a blended space (Benyon, 2013).

The physical space combines a 13.3" screen illustrated by Figure 18, fixed on a regular bus stop pole with wireless connectivity. One of the benefits of using e-paper technology is the low energy consumption, allowing it to be self-powered.

Figure 18 - 13,3-inch E-paper Display (Waveshare, 2021)

The proposed solution with the changeable interface consumes too much power to be self-powered by a solar panel. The e-paper device uses no power once the image is displayed. Still, real-time information demands more energy as the interface keeps changing to feed the display with data on arrival times, time, climate and news information. That is why the proposed solution of the interactive e-paper stop will have the power connected to the grid. The cables will be bound by the underground lines provided by an energy entity, needing to be added a small power meter, as Figure 19 shows an example, on the casing hardware.

Figure 19 - Example of Power Meter (SIA Joom, 2021)

The physical environment that the interactive e-paper bus stop will be on is one of the poles of the bus stops, sometimes supported by the shelters for people to wait on. A casing will embrace the display with IP67 rating compliant material with electronic compartments for battery and all electronic assembly. The IP rating is critical because it indicates the degree of protection that the material provides from severe conditions, such as dust, sand, rain and snow. The compliant material can be plastic (polycarbonate, polypropylene) or aluminium. Future research may test to indicate which material fits better the case for the e-paper display. From the design perspective, the rendering of the case will be designed as polypropylene, allowing the case to have colour and personalisation, as seen in Figure 20.

Figure 20 - 3D Casing (From the Author, 2021)

For screen protection, the pole will require a toughened safety glass. A Grade A safety glass is indicated in this case because it breaks into small blunt-edged pieces on impact, reducing the risk of injury and significant glass breakage (Viridian Glass, 2019). Also, for better visualisation at night, LED lights inside the framing can help visualise all information, as Figure 21 shows. The time verification systems trigger the lighting by the back-end.

Figure 21 - LED Lights (From the Author, 2021)

The experience will be multi-layered: the physical case will hold the e-paper display, and the digital space will start with the primary information on the screen. On the e-paper, the interaction where the information changes will happen at the push of a button, indicated by Figure 22.

Figure 22 - Buttons (From the Author, 2021)

Therefore, access to more content in the digital space will happen in an interaction with the physical space. User validation will help to define if the solution is better experienced with one or two buttons. If needed, the 3D prototype will be modified, and only one button will be available for toggling the interface. The size of the casing is based initially on the size of the 13,3" screen, as the rest is designed to accommodate the hardware, with content managing, communication of screens via Wi-fi or 3G, battery and power supplies, power meter and flexible LED light strips. The sizes of the casing are illustrated in Figure 23.

Figure 23 - Casing sizes (From the Author, 2021)

The idea for the casing to be longer is to accommodate the hardware, being better distributed along with its height. In that way, the case can be thicker and more visually appealing. As this dissertation focuses on the user needs and front-end interface and design, the length of the casing can be assumed. Still, future research can help define all the hardware needed to run a physical prototype of the proposed solution.

5.6. Prototyping

Benyon (2013) reported that a prototype is a concrete but partial representation or implementation of a system design. The outcome of all the research methods and findings has its results represented by the prototype. Prototypes excel in presenting solutions since they involve creating a minimal viable product (MVP). They let people experience the actual flow of the system, meaning that this deliverable will be crucial to let them evaluate the solution. Designing the prototype is essential because it allows some potential users to test its usability and suggest improvements to its design or system.

The prototype is very similar to the wireframes because the colours provided by the e-paper display will be shades of grey. The prototype is shown along with the 3D prototype of the interactive e-stop casing, as Figure 24 demonstrates. It was made with prototyping tools software such as Figma and Photoshop, while the 3D rendering was made with Solid Works rendering software. Detailed images of the prototype can be found in Annex 3.

Figure 24 - Final Prototype Screens (From the Author, 2021)

The information displayed can be grouped by dynamic and static information. All the static information displayed are the ones that real-time information does not apply to, such as bus stop name and designated code, which Andante zone the stop belongs to, the bus line numbers and destinations, names of bus stops of the entire route with the dedicated Andante zone, QR code with information of all timetables of that specific line and more details on STCP. Other static information is on the second screen, with a map of the area, indicating nearby places, the captions on the connections by bus or metro. The dynamic information is the one that the display will keep on refreshing and demanding more power. Refresh time is by the minute on the time and arrival times. Other real-time information such as climate and news can refresh onto new information by the hour. The ads displayed by the second screen are changed depending on deals made between transit agency and advertiser. As described by chapter four, the real-time data is fed by back-end data through an internet connection and converted into files supported by the e-paper software.

Sociedade de Transportes Colectivos do Porto (STCP) provides all the information on bus lines, timetables and routes inside the interface, which are tested and validated; the author does not define the information. The core information of Porto's public bus system, such as bus stop identification, numbers and names of the stops, full itinerary of the line and information on accessibility, are similar to the ones located in other places. For comparison reasons, Figure 25 illustrates the data on bus stops in London, England, provided by Transport for London.

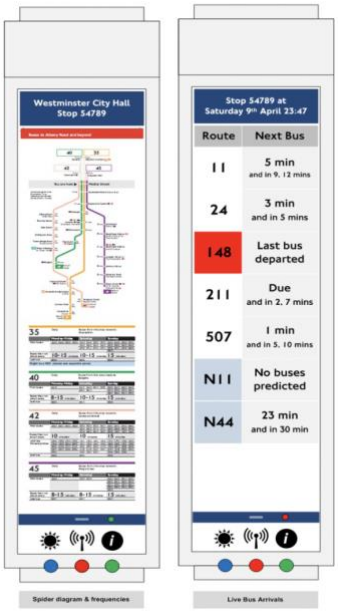


Figure 25 - Transport for London bus information (Transport for London, 2015)

Transport for London provides the same core information as the STCP: bus stop identification, number and name of the stops supported by that designated bus stop and full itinerary. This comparison is important to illustrate that the transport agency will provide the information on the display. This consistency is also valuable to see if the proposed solution could be replicable in other places, with the information supported by other transport entities.

6. User Evaluation

6.1. Introduction

Usability studying, or evaluation is the human-design-centred approach to evaluating a product or service with representative users. According to Moran (2019), usability evaluation goals may differ from what the entity wants to assess by the study. Still, they usually include identifying potential problems and uncovering opportunities to improve and learn about user preferences and behaviours. These observations of the actual users are crucial for a better outcome for the people experiencing it in real life.

The usability evaluation performed by this study will be the qualitative kind. Qualitative usability evaluation focuses on getting insights, findings, and incidents about using the product or service by the participants. Qualitative usability evaluation is best for discovering problems in the user experience (Moran, 2019).

The core elements for performing a usability test are the facilitator, the tasks to be performed, and the participant as an actual user of the product or service being studied. The facilitator administers schemes to the participant. As the participant performs these tasks, the facilitator observes the participant's behaviour and listens for feedback (Moran, 2019). The tasks are realistic activities that the user will have to perform when using the service in real life. In terms of the number of users, in research from Nielsen (2001), it is enough to test with 3–5 users. The evaluation with more than five users wastes resources, reducing design iterations and compromising the final design quality.

The goals of this evaluation work will be:

- See if the user is familiar with the technology and enjoys the experience.
- Discover what the primary information that meets the eye is.
- Evaluate the information displayed, if it meets the needs of the bus passenger in terms of timetables information.
- Evaluate the satisfaction with the secondary information - climate, news and ads.
- Evaluate the interaction of the blended solution (physical and digital).
- Perform a cognitive walkthrough to see if the font and image sizes are legible.
- Get comments on the learnability of the buttons.
- Check the consistency of the systems with the branding guidelines of the STPC bus network.

- Obtain review and comments on the interface.

6.2. Usability Model

Achieving usability requires us to take a human-centred approach to design and adopt a central evaluation approach (Benyon, 2013). In research from Jakob Nielsen (1993), before any evaluation is conducted, the type of approach to users' needs to be clarified for evaluation to impact the analysis significantly. The evaluation to be undertaken by this dissertation will be the formative kind. Formative evaluation helps improve the interface as part of an iterative design method. The primary purpose of formative evaluation is to determine which detailed aspects of the interface are good and bad and how the design can be improved.

The goals set for the usability evaluation to be a success are recruiting real users from the Porto public bus network to better evaluate the consistency and efficiency of the information displayed, meeting the user's goals when needing information on bus stops.

6.3. Results

The usability testing took place by an online meeting platform, where each session took about 20 minutes. The number of users who performed the testing individually complied with Jakob Nielsen's method of three to five users (2001). The age group was distinct to evaluate the solution from different age groups, as Table 2 demonstrates. All users are real passengers from Porto's public transportation system, so they were familiar with the names of bus stops, lines and itineraries. The facilitator of the evaluation was the author of the dissertation.

Table 3 - Participant's Information

User	Gender	Age Group	Occupation	Frequency of Use of Bus Public Transit
1	Male	25-30	Operations Specialist	1x week
2	Female	30-35	Prefers not to say	4x week
3	Female	55-60	Lawyer	1x week
4	Male	40-45	Entrepreneur	2x week

The usability evaluation, as mentioned before, was a formative evaluation method, so the users were asked to be thinking out loud as a way for the researcher to understand the whole experience that the interactive e-paper stop could provide. A thinking-aloud test involves having a test subject use the system while verbalising their thoughts. With this, users enable the researcher to understand how they view the computer system, and this again makes it easy to identify the users' major misconceptions (Nielsen, 1993).

An introduction of the research was presented, along with the digital prototypes to be evaluated. Then, the participants were asked to think out loud as they were going through the interface. After, they performed evaluations on specifying settings asked by the facilitator, meeting the requirements to achieve the goal of the usability evaluation described at the beginning of this chapter. They were asked permission to be recorded for the author to document the results, as Table 3 illustrates the usability evaluation results.

Table 4 - Performance of Tasks

Goal	User 1	User 2	User 3	User 4
Familiarity with the technology	Good familiarity; enjoys the experience.	Good familiarity.	Little familiarity.	Little familiarity.
Primary information	The number and name of the bus line.	The bus line that is arriving and the other estimated times.	The number and name of the bus line.	The name of the bus line and how long the wait is.
Secondary Information on the first display	The QR code that leads to schedules.	Where on the way the bus line is and what are the next stops.	How long the wait is.	The route of the bus lines.
Cognitive walkthrough	Overall it is good, but the user finds it hard to read the name of the lines.	Good readability. All information is clear.	Overall is good but has difficulties with the letter spacing.	Overall it is good, but it took some time to understand the information in shades of grey.
Seek for physical interaction and changing of screens	One button can be enough.	The icons on buttons are confusing, but two buttons allow one to understand that the screens are interchangeable.	The icons on the buttons are confusing. One button can be enough.	The first icon is confusing. One button is enough.
Evaluation on the necessity of information of climate, ads and news	Very interesting to enjoy knowing the surroundings and connections with other bus lines and metro stations.	The map is very useful with complete information, space for announcements and news is innovative, date, weather and entity information is fascinating.	Very interesting, much needed.	The map of the area is excellent, and knowing the climate and news is much appreciated.
Overall comments	The arrival times are the most interesting. A secondary screen is valuable.	The estimated arrival time is an essential feature. Icon for the first button to be a letter "I" for information.	Suggestion to provide a visual guide of how to use it.	The solution is very beneficial and makes the experience more enjoyable. The display could be coloured.

After evaluating each user individually, all performances were compared to seek the most severe problems. According to Krug (2009), the focus after a usability test should be ruthlessly on the most serious problems. There are two things to be considered to determine the severity of the problems encountered: the number of users that experienced the same problem and whether it will cause a serious problem for people who will experience this in the future or is it just an inconvenience.

The most severe problems were the ones that more than half of the users evaluated encountered: the number and icon of the buttons and legibility of the bus lines. The author will consider these problems for improvements to the proposed solution. Another comment by an older user was valuable. Not everyone is familiar with the e-paper technology, so for the experience to become more user-friendly, instructions on using the e-paper bus stop can be presented for the users.

6.4. Improvements

The usability evaluation was a crucial part of the methodology because it allowed the author to have constructive feedback on the proposed solution of the e-paper interactive bus stop. Adopting the research from Krug (2009), the focus on adjustments were on the most serious problems that the users encountered. STCP provides all the information on bus lines and timetables, so the focus was on improving the cognitive problems and the physical interaction. Figure 26 illustrates the improvements made.

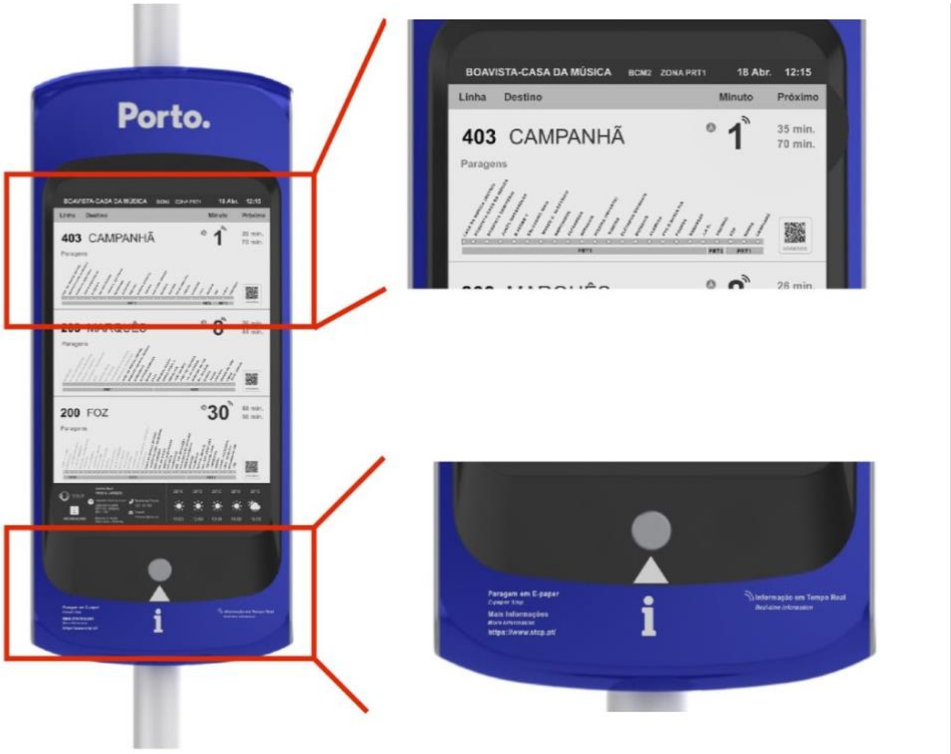


Figure 26 - Prototype Adjustments (From the Author, 2021)

After the feedback to assess the most serious problems encountered by the users, the author adapted the model to add features and enhance the ease of usability. The main changes were signalling that the estimated arrival time was updated in real-time, switching from two to only one button that toggles between the screens and minor improvements in the readability of the bus stop names. Some information was added to the casing in the form of decals explaining how the interactive sign works, an information icon pointing to the button and the aforementioned signalling of real-time information.

7. Conclusions

After performing all the phases of the design thinking methodology, it was possible to conclude how the interactive e-paper stop would look like and how the Portuguese public would react to it. Empathising with real users, defining the proper scope of the problem, ideating potential solutions, prototyping the best one, and refining it with the usability test's help was crucial for answering the research questions and delivering a solution that meets the user's needs and goals. Porto's public bus network was used as an example for the interface and its interactions.

Since the usage of the e-paper technology is key to this innovative solution, the acceptance of this technology's experience was vital to continuing to perform this study. The discovery phase helped the author to better scope the problem and how the solution could be designed. Along with the e-paper display, the 13" format screen and physical interaction with the user by a button were defined. It was also possible to conclude parts of the industrial design of the casing that will hold the e-paper with the button and digital interactions on the display.

About the information that should appear on the interface, the human-centred design approach helped design an interface that meets the user's needs when needing scheduled information from the bus stop. The interaction on the display allows it to deliver more information than the static paper and signs that already exist in these places. The interaction also allows the display to perform real-time data, which the quantitative research helped highlight as a prominent feature. The study of how real-time information works and its implications with the back-end information that translates on display was essential to seek the feasibility of the interactive e-stop. A third-party entity can provide all this data. Some agencies, such as GTFS-RT, developed by Google, provide a free alternative to avoid the expense and risk of building a proprietary system to convey real-time information.

Testing the proposed solution by the usability evaluation of the interactive e-stop was crucial for the objective of this dissertation. When testing a real scenario, there were some constraints because the access for this technology while displaying the interface is not simple like testing an app through a phone. Therefore, recruiting actual users of the STCP (Porto's Public Transportation) system was crucial for trying to perform an accurate scenario while using an online tool for the testing. By performing tasks and gathering feedback by the usability testing, the most serious problems were highlighted and improved.

We can conclude that an interactive e-paper bus stop in the Porto region is feasible and also desirable to its public. One of the main goals of this dissertation was to analyse the reaction of users to this innovative solution and if they feel it could be beneficial to them. This goal was achieved and overcame the author's expectations when almost 98% of interviewed users affirm that they enjoyed the experience that the e-paper technology provides. This technology is the core of the whole study, and if the users didn't like it, it could cause trouble with the direction taken towards the conclusion of this dissertation. Additionally, the other goal of this dissertation was to answer how this interactive e-paper bus stop would look like. With the human-centred design approach by asking the users how this solution could better attend to their needs, this goal was also achieved.

This dissertation demonstrated an innovation process using Design Thinking in the context of a new e-paper interactive device for public transportation, opening the prospect of future work, analysing costs for developing and implementing this solution by better structuring the casing, testing materials, injection moulds, batteries and power supplies. This work can provide a real-size prototype that can again be tested with real users. It also opens up the possibility of the studying and usage of more than one e-paper display screen, joining multiple screens together.

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Appendix A

Questionnaire Questions

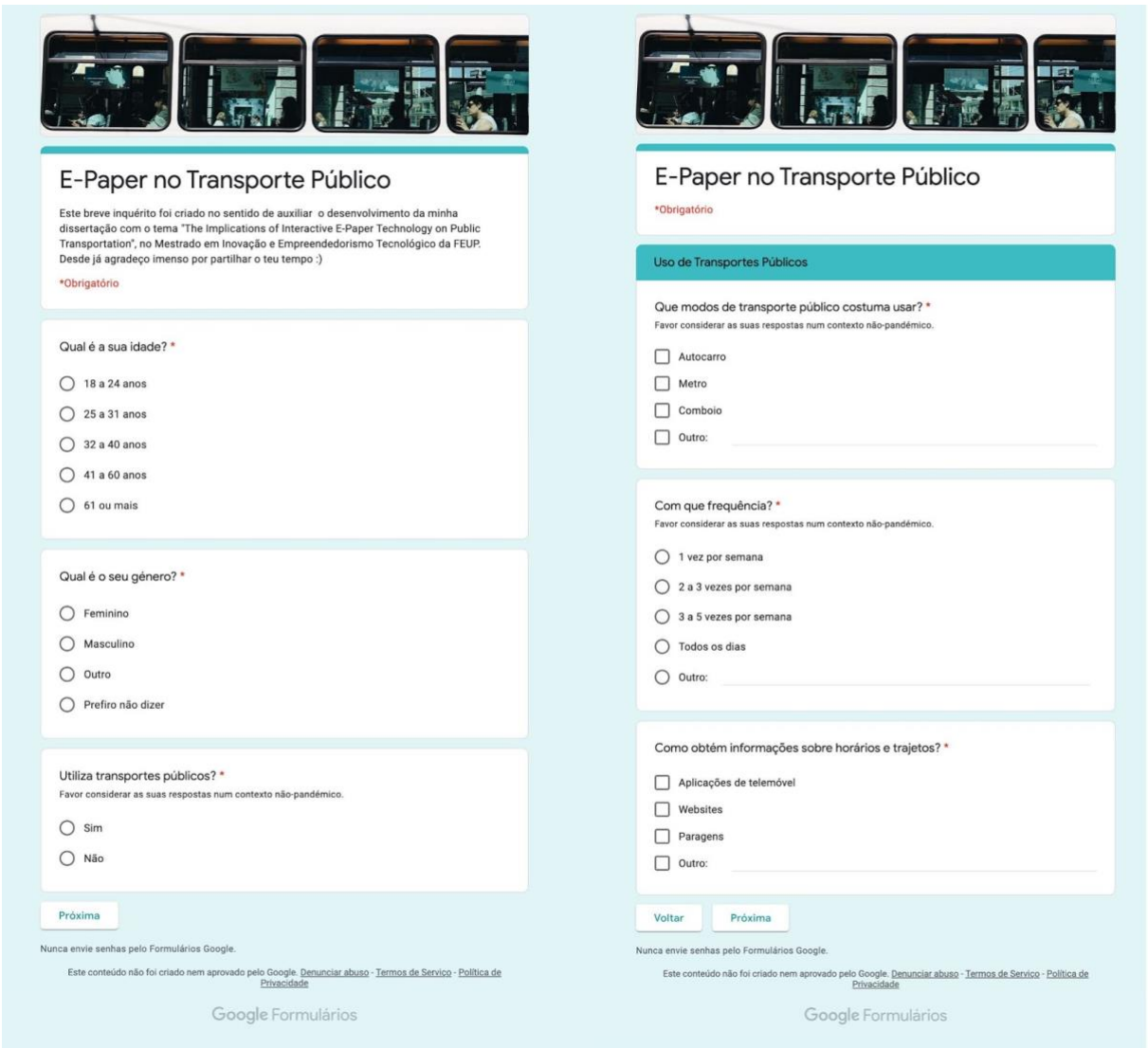


Figure A.1: Questionnaire Pt 1

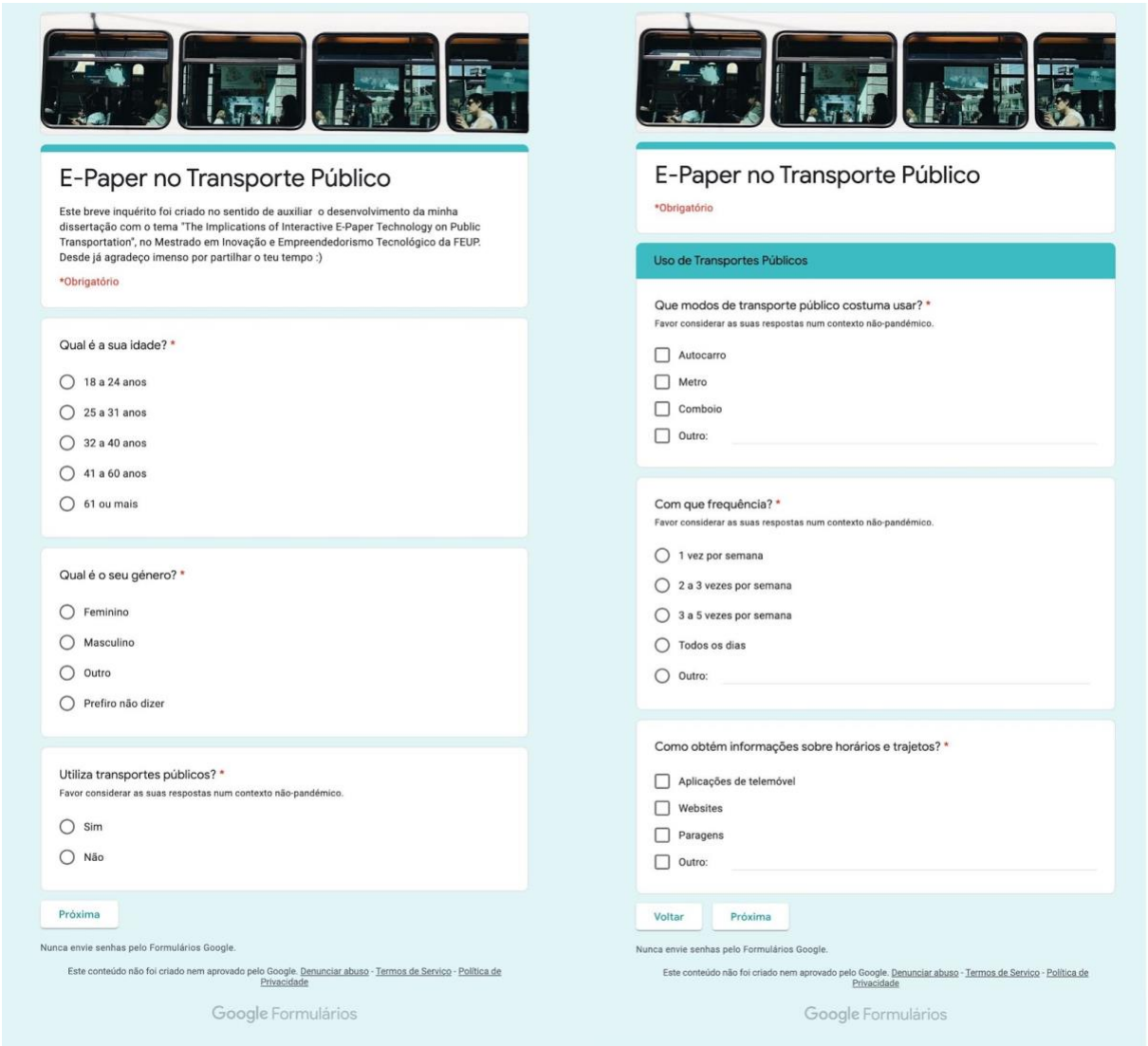


Figure A.2: Questionnaire Pt 2

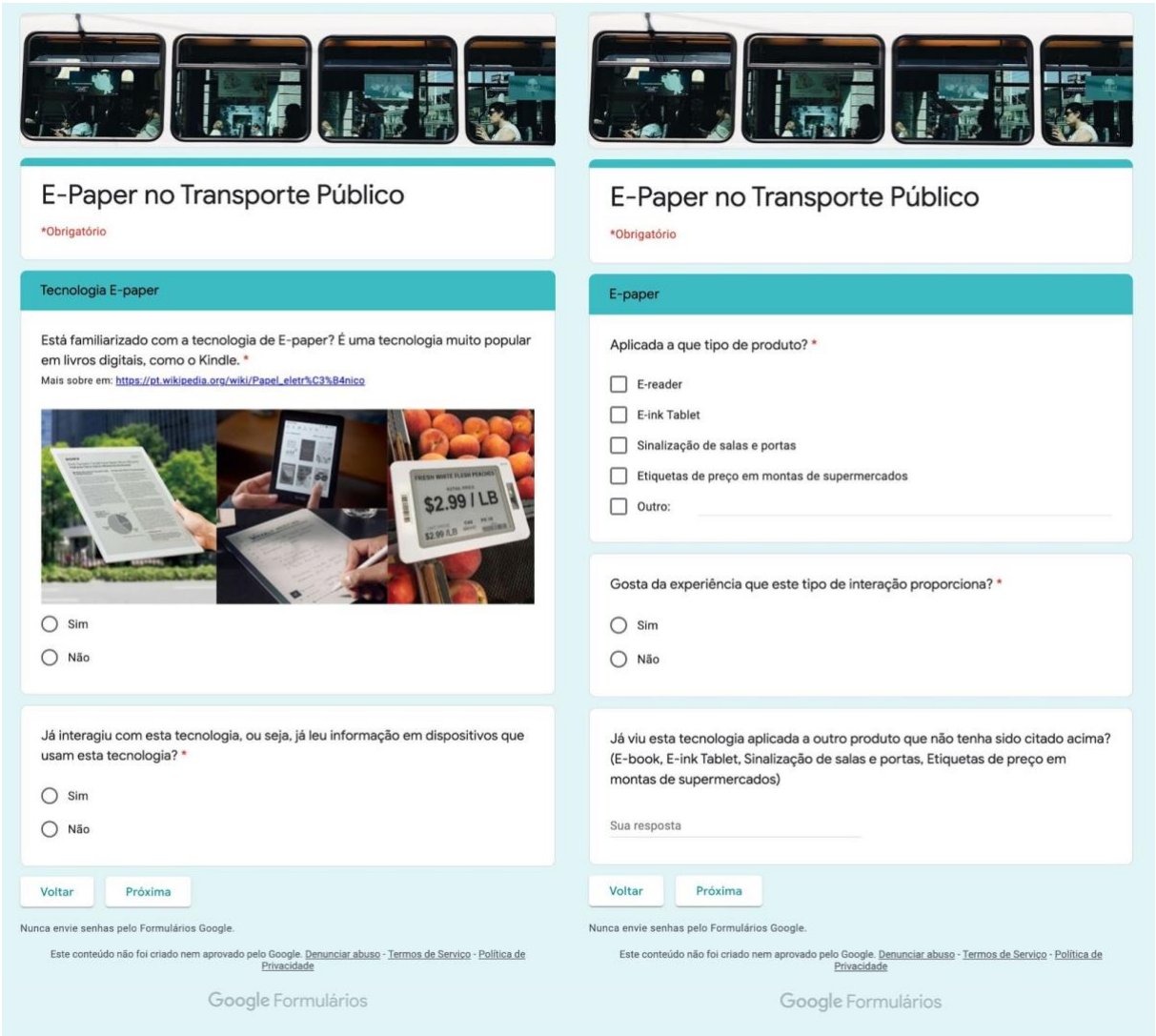
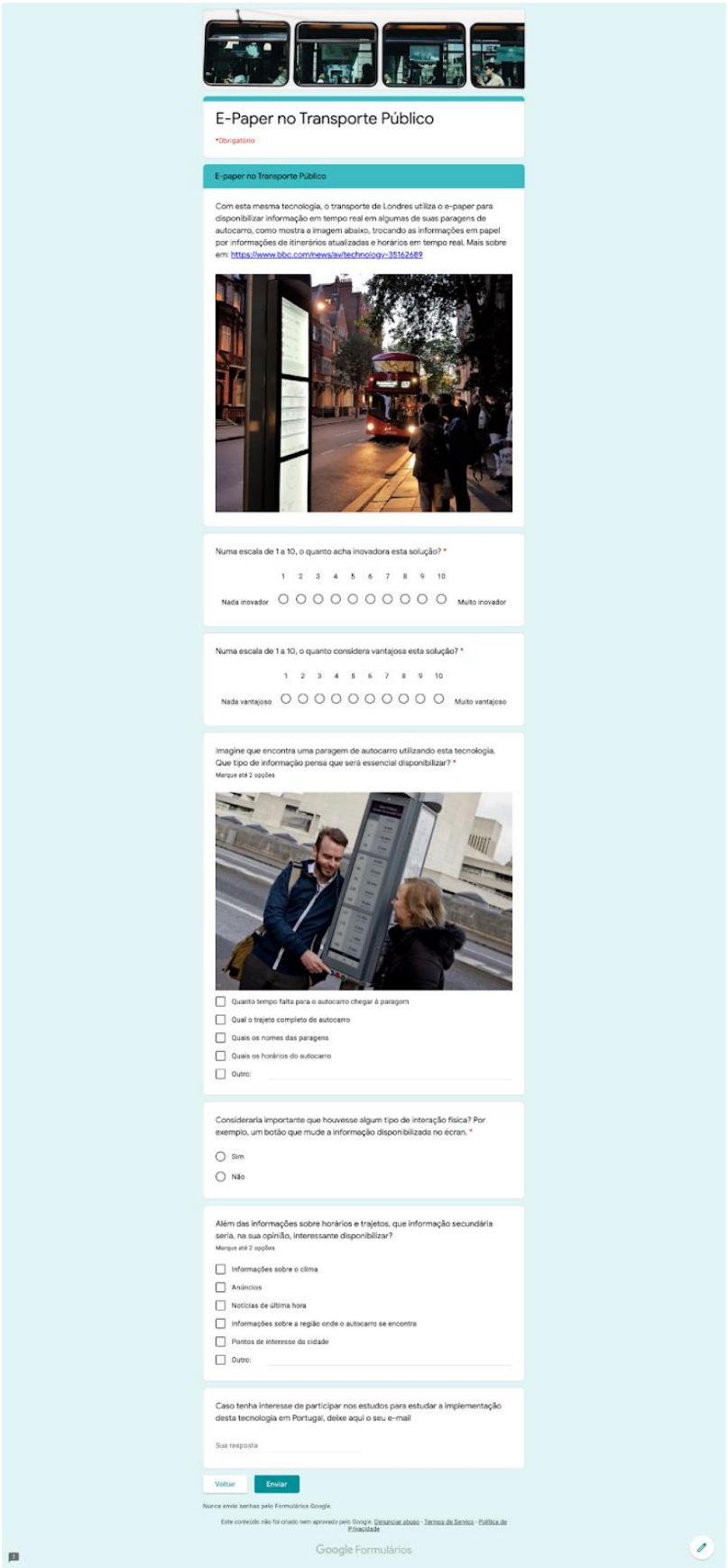


Figure A.3: Questionnaire Pt 3



E-Paper no Transporte Público

*Obrigatório

E-paper no Transporte Público

Com esta mesma tecnologia, o transporte de Londres utiliza o e-paper para disponibilizar informação em tempo real em algumas de suas paragens de autocarro, como mostra a imagem abaixo, trocando as informações em papel por informações de itinerários atualizadas e horários em tempo real. Mais sobre em: https://www.bbc.com/news/av/technology-35162689

Numa escala de 1 a 10, o quanto acha inovadora esta solução? *

1 2 3 4 5 6 7 8 9 10

Nada inovador Muito inovador

Numa escala de 1 a 10, o quanto considera vantajosa esta solução? *

1 2 3 4 5 6 7 8 9 10

Nada vantajoso Muito vantajoso

Imagine que encontra uma paragem de autocarro utilizando esta tecnologia. Que tipo de informação pensa que será essencial disponibilizar? *

Marque até 2 opções

- [ ] Quanto tempo falta para o autocarro chegar à paragem
- [ ] Qual o trajeto completo do autocarro
- [ ] Quais os nomes das paragens
- [ ] Quais os horários do autocarro
- [ ] Outro:

Consideraria importante que houvesse algum tipo de interação física? Por exemplo, um botão que mude a informação disponibilizada no écran. *

- ( ) Sim
- ( ) Não

Além das informações sobre horários e trajetos, que informação secundária seria, na sua opinião, interessante disponibilizar?

Marque até 2 opções

- [ ] Informações sobre o clima
- [ ] Anúncios
- [ ] Notícias de última hora
- [ ] Informações sobre a região onde o autocarro se encontra
- [ ] Pontos de interesse da cidade
- [ ] Outro:

Caso tenha interesse de participar nos estudos para estudar a implementação desta tecnologia em Portugal, deixe aqui o seu e-mail

Sua resposta

Voltar Enviar

Nunca envie senhas pelo Formulários Google.

Este conteúdo não foi criado nem aprovado pelo Google. Denunciar abuso - Termos de Serviço - Política de Privacidade

Google Formulários

Figure A.4: Questionnaire Pt 4

Appendix B

Questionnaire Results

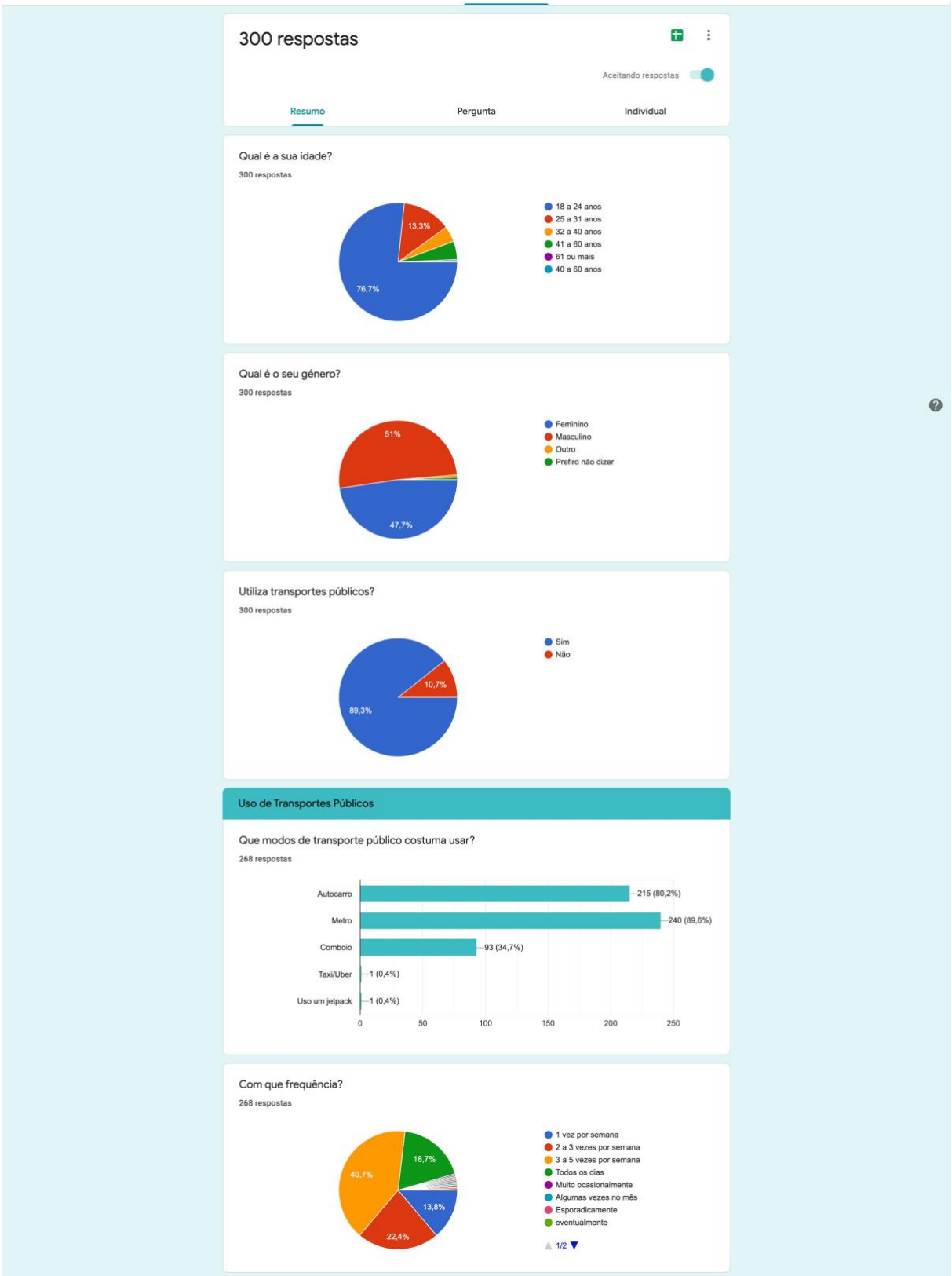


Figure B.1: Results of Questionnaire Pt.1

Figure B.2: Results of Questionnaire Pt.2

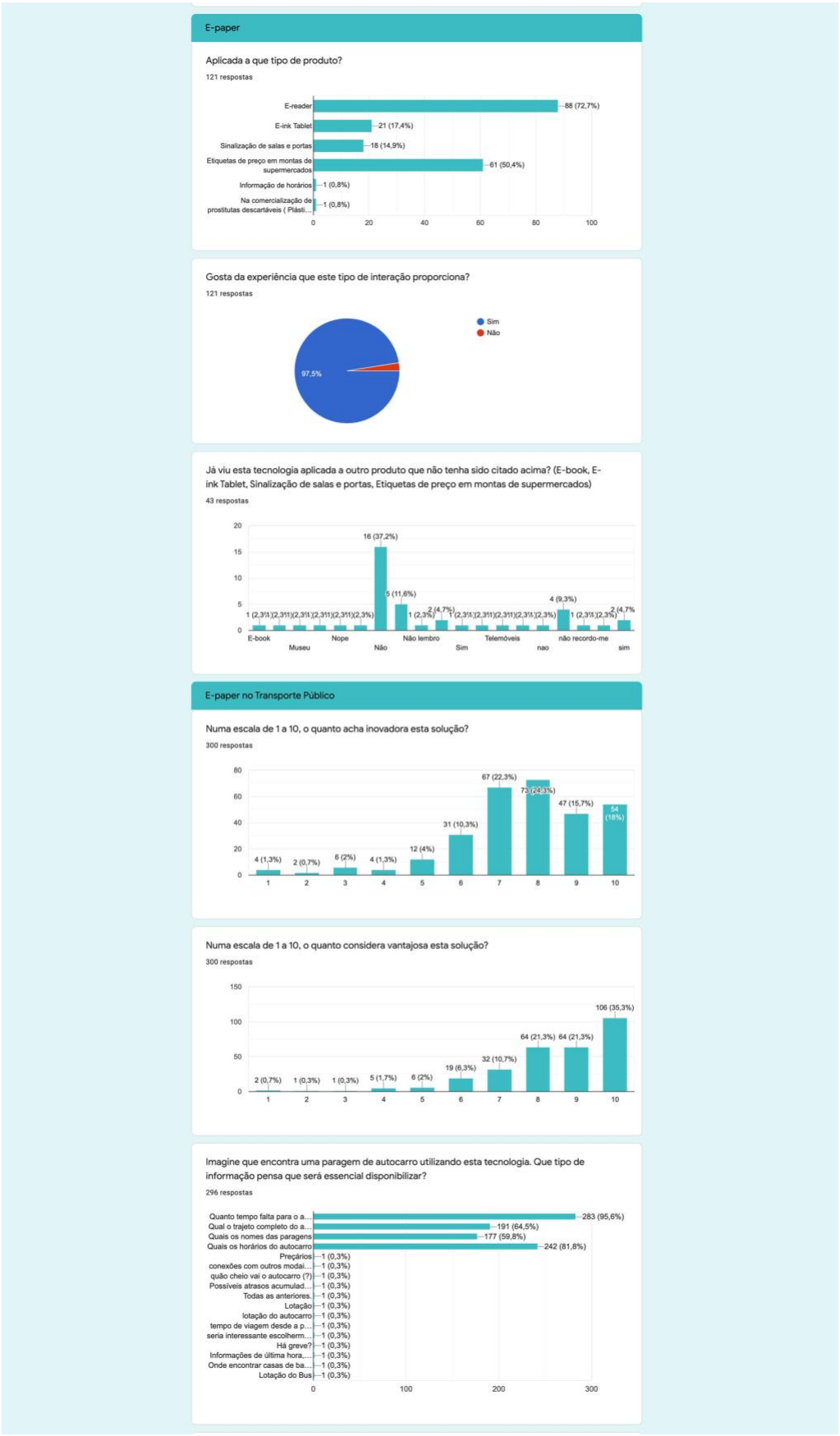


Figure B.3: Results of Questionnaire Pt.3

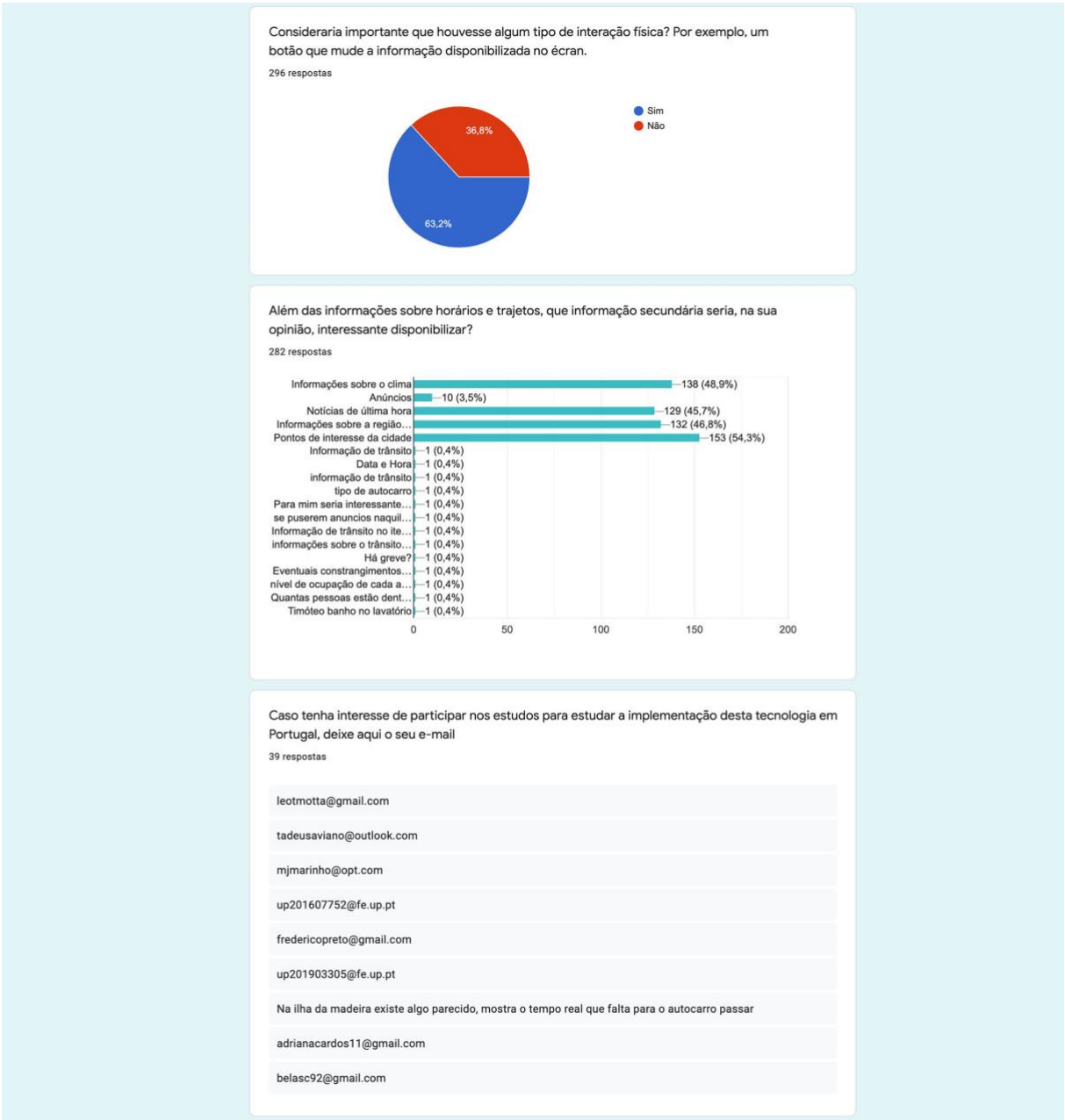


Figure B.4: Results of Questionnaire Pt.4

Appendix C

Prototype Images

Figure C.1: Final Prototype

Figure C.2: Information on the casing

Figure C.3: Final Prototype Second Screen