Universidade de Aveiro
Ano 2019

Departamento de Economia, Gestão, Engenharia Industrial e Turismo

Inês Moutinho Monteiro

Novas soluções para a interação entre operador e passageiro nos transportes públicos

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New solutions for the interaction between service provider and passenger in public transport

Relatório de Projeto apresentado à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Engenharia e Gestão Industrial, realizada sob a orientação científica do Professor Doutor José Vasconcelos do Departamento de Economia, Gestão, Engenharia Industrial e Turismo da Universidade de Aveiro

“She believed she could, so she did.”

-R.S. Grey

o júri

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agradecimentos

Gostaria de agradecer a um grupo de pessoas que, direta ou indiretamente, contribuíram para a realização deste projeto.

Em primeiro lugar, gostaria de agradecer à equipa da OPT pela oportunidade que me deram e por me terem integrado tão rapidamente.
Ao Doutor Fernando Vieira e à Engª. Sandra Lameiras um agradecimento especial por me terem dado plena liberdade para desenvolver o projeto.
Agradeço ao Paulo Espinha pelas conversas, sempre interessantes, e conhecimento que me foi transmitindo ao longo do ano. E à Carmo Reis, que me deu amparo e motivação quando era preciso.

Agradeço ao Professor Doutor José Vasconcelos que, para além da orientação dedicada e profissional, permitiu-me que desenvolvesse um projeto do meu interesse e com ambição para o futuro.

Um especial agradecimento aos meus amigos João, Cristina e Mafalda que me ajudaram ao longo deste estranho ano e que tornaram tudo mais divertido.

Por último, agradeço aos meus pais e irmão que me deram todas as condições para terminar o curso com sucesso e demonstraram interesse pelo meu trabalho. E ao Bernardo que, ao longo dos anos, esteve sempre presente.

palavras-chave Mobilidade urbana, transporte público, Smartphone, UML, lean startup

resumo

Ao longo dos anos, a consciencialização das populações relativamente ao meio ambiente tem vindo a aumentar. O setor dos transportes, nomeadamente o de passageiros, tem um grande impacto na emissão de gases poluentes e, por isso, a utilização do veículo próprio como meio de transporte de eleição tem de ser reduzida. Para isto, é necessário que o transporte público se torne apelativo e sirva as necessidades das pessoas de forma personalizada e com qualidade.

Este projeto é desenvolvido de acordo com a premissa de melhoria da qualidade dos transportes públicos e baseia-se na troca de informação para atingir este objetivo. O desafio lançado pela OPT assenta na criação de novas soluções para a interação entre operador e passageiro.

Tendo em conta que a OPT está sediada no Porto, a sua área de intervenção por excelência foca-se na Área Metropolitana do Porto (AMP) e, por isso, o projeto focou-se na aquisição de dados desta mesma área para a caracterizar em termos de mobilidade. O estudo tem a AMP como ponto de partida, no entanto, o objetivo é criar uma solução que seja escalável para qualquer cidade.

Para analisar o estado da informação ao público na área metropolitana do Porto, procedeu-se ao levantamento da oferta e à realização de um inquérito aos passageiros. Apesar de existir alguma oferta relativamente a aplicações móveis que disponibilizam informação, existem oportunidades de melhoria no contexto da integração de funcionalidades essenciais e *user experience*. Além disso, a evolução indica uma interação entre os intervenientes de forma a que se possa gerar informação relevante a partir do feedback do utilizador.

Desta forma, foi concetualizado um novo modelo de aplicação móvel para os transportes públicos. O objetivo é baseado na co-criação de valor para melhorar a qualidade do serviço e permitir uma mobilidade contínua, motivando assim para a utilização dos transportes coletivos. Tendo em conta o potencial comercial deste projeto, reflete-se sobre as estratégias de inovação e negócio tendo por base a otimização dos recursos e o valor para o cliente.

Key words Urban Mobility, public transport, Smartphone, UML, lean startup

abstract

Environmental awareness has been increasing over the years. Since the transportation sector is one of the great contributors of greenhouse gas (GHG) emissions, it is necessary to motivate people to leave their car at home and use public transport. However, service providers must meet passengers' needs in a more personalized way and improve the quality of the service they offer.

This project aims to provide a tool that positively impacts the required shift towards sustainability, and it relies on the exchange of passenger information to achieve this goal. The challenge proposed by the company, OPT, is based on the creation of new solutions for the interaction between operator and passenger through the Smartphone.

Given that OPT is headquartered in Porto, its area of intervention *par excellence* is focused on the Metropolitan Area of Porto (MAP). The project focused on the acquisition of passenger data from this same area to characterize it in terms of urban mobility. The study has the MAP as a starting point however, the goal is to create a solution that is scalable to any city.

The project began by characterizing the current situation regarding passenger information in the metropolitan area of Porto and a passenger survey was conducted to understand their perception towards information in public transports. Despite the available app offer, there are opportunities for improvement in the context of the integration of essential app functionalities and user experience. In addition, a bilateral interaction between the two stakeholders is needed in order to generate relevant information from user feedback.

In this way, a new mobile application concept for public transport was designed to co-create value and improve the quality of service and allow seamless mobility across the travel network. Taking into account the commercial potential of this project, the strategies of innovation and business are based on the optimization of resources and value for the client.

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List of Abbreviations

AP: App Usage Potential

API: Application Programming Interface

ATMS: Advanced Transportation Management System

AVL: Automatic Vehicle Location

AVs: Autonomous Vehicles

BF: Bike-Friendly

BOS: Blue Ocean Strategy

BP: Business Plan

DF: Disabled-Friendly

DRT: Demand Responsive Transport

EC: European Commission

ETA: Estimated Time of Arrival

EU: European Union

EVs: Electrical Vehicles

FCUL: Faculty of Sciences of the University of Lisbon

FEUP: Faculty of Engineering of the University of Porto

GC: General Characteristics

GDPR: General Data Protection Regulation

GHG: Greenhouse Gas

GIST: Integrated Management of Transport Systems

GP: Good Practices

GPS: Global Positioning System

GTFS: General Transit Feed Specification

ICT: Information and Communications Technologies

INEGI: Institute of Science and Innovation in Mechanical Engineering and Industrial Engineering

IoT: Internet of Things

IS: Infrastructure

ITS: Intelligent Transport System

LBS: Location Based Services

LC: Lean Canvas

LS: Lean Startup

MA: Metropolitan Area

MaaS: Mobility as a Service

MAL: Metropolitan Area of Lisbon

MAP: Metropolitan Area of Porto

MVP: Minimum Viable Product

OMT: Object Modelling Technique

OMT: Object Modelling Technique

OOSE: Object Oriented Software Engineering

OPT: Optimização e Planeamento de Transportes

PI: Passenger Information

PIS: Passenger Information System

PN: Portuguese Norms

PT: Public Transport

SMEs: Small and Medium-sized Enterprises

SP: Smartphone

TI: To Improve

UML: Unified Modelling Language

1. Introduction

1.1. Context of work

This project represents the conclusion of a Master's degree in Industrial Engineering and Management undertaken at the University of Aveiro.
By choosing a project-oriented thesis the goal was to apply knowledge to situations of practical interest which involved the adoption of appropriate methodologies to tackle a specific challenge proposed by a company. I opted for OPT (Optimização e Planeamento de Transportes) since it is a technological company operating within the urban mobility sector. In addition, as a small company, OPT provides an environment where people are easier to approach, and I had the opportunity to learn quickly and in depth by cooperating closely with experienced co-workers.

The chosen topic involves technology and urban mobility. My first contact with the topic of the future of urban mobility happened during the Erasmus program in Finland with the "Transport Transformation" curricular unit. The contents addressed were of great interest and I realized that this sector is evolving fast by constantly adopting new and more sustainable technologies. The proximity with cutting-edge technologies and the emergence of better mobility systems motivated me to start a career within this sector. In this sense, I hope that this project will contribute to the major goal of improving the quality of life in urban centers through an integrated, seamless and sustainable public transport network that is adaptable to customers' needs.

Industrial Engineering is not merely connected to factories and production lines. We can look at cities as a huge enterprise that needs to be optimized either by managing its current resources more efficiently or by creating more advanced systems that integrate technologies and knowledge from various sectors. For this reason, I chose to work within the service sector and although the industrial component is not present in this work, the mindset based on continuous improvement, critical sense, importance of statistics and data processing to support decision making was quite useful and applied throughout the project. These were instilled during the academic training and allowed me to develop the project in a more practical and results-oriented way.

1.2. Project

OPT emerged in 1992 and develops products in three different areas of the sector: operations management to transport operators, passenger information and consultancy in urban mobility.

The challenge proposed by OPT is in the scope of passenger information within the public sector and the Smartphone was identified as the ideal tool to improve the provision of passenger information and capture their opinion about the service. The goal is to enable easier communication and generate relevant data for the parties involved by creating a new concept of mobile application that is based on user needs, technological requirements and necessary information. There are several mobile applications on the market that allow interaction between operators and users of the service, however, these can be improved regarding information provision, usability, accessibility and do not serve individual needs accurately.

Nonetheless, in order to characterize the challenge, it was necessary to understand the topic of urban mobility more thoroughly along with other related aspects. It was also important to analyze the passenger information provision and its emergent opportunities. The assessment of the quality of passenger information within the MAP (Metropolitan area of Porto) highlighted the need for real time information. Then, by combining this knowledge with good practices implemented in benchmark cities and depicting the technological requirements it was possible to reflect on a new concept of interaction.

1.3. Structure of the report

The project report begins by presenting relevant literature for the topic in chapter 2. It starts with urban mobility to contextualize the reader in the current panorama and future developments, then the relevant parameters for passenger information are depicted (communication channels and available information according to the phase of the trip). The Smartphone is presented as the main communication channel in the sector in the near future. A brief description of the UML (Unified Modelling Language) diagrams is presented to specify the technical language used to conceptualize the app. Then, three innovation and business methodologies/ theories are discussed to support the strategies used to deal with the concept as a potential product. Finally, some legal aspects related to customer satisfaction of passengers in public transportation in Portugal and protection of personal data are presented.

Chapter 3 presents the project in the context of the company. It includes a detailed presentation of the company as an organization, its business areas and respective products as well as customers. Next, the proposed challenge is clarified in more detail and, finally, the project methodology is explained.

Chapter 4 begins with the analysis of the current situation regarding the information to the public in the MAP. The channels and types of information available in the MAP are identified and then the conditions for conducting the passenger survey and respective results are presented. A comparative analysis is made between the supply and demand of information to understand what must be done in the future to respond to the needs of the passengers. Next, a new concept of mobile application is presented with the necessary technological requirements. Finally, a proposal of innovation and business strategies are presented for further discussion and potential implementation.

Chapter 5 includes a reflection on the project developed, an analysis of its contribution and future developments that may arise from it.

2. Literature Review

2.1. Urban Mobility

This section depicts the main factors affecting the current state of urban mobility. Urban mobility is defined as the way people and goods circulate within the city to foment economic development and social activities (Foth 2009). Such mobility is based on motorized and non-motorized vehicles and the required infrastructure to enable daily commuting. The quality of mobility is intrinsically related to the articulation between different agents such as transportation, transit, circulation, accessibility, urban development and land use. Other than promoting environmentally friendly policies, the goal is to reduce the inequalities in access to transport while guaranteeing the right to access the city in a fair and dignified way to every citizen.

2.1.1. Current panorama of Urban Mobility

The world is evolving more rapidly compared to the previous century. People's perceptions on society, economy, environment, cities, technology and organizations are changing due to the increasing pressure of population growth. Cities are becoming megacities and the demand for new mobility solutions is challenging the urban ecosystem. Consumers are more aware of their environmental footprint and the impact of daily habits regarding mobility is motivating the choice of more sustainable modes of transport.

Reflecting on mankind's recent evolution, the development of urban mobility systems did not follow the same pace of the rapid growth witnessed in other areas, such as technology or even education. This phenomenon combined with growing environmental concern led to public and private initiatives to improve mobility services rom which are now starting to benefit (Kamargianni et al. 2016, p. 3296). Some trends are staring to occupy the city landscape and, as shown in figure 1, the shift towards decarbonization and soft vehicles (such as bicycles) is somehow appealing. Cities become less crowded with motorized vehicles leaving more space for the human being to experience the city as a living and seamless ecosystem. Figure 1 presents a pleasing view of what the future might hold as the smart city concept starts to gain traction through connectivity, automation and electrification.

Figure 1 - Bosch solutions for urban mobility - retrieved from Bosch (21/11/2017)

According to the European Commission (EC) reports, by 2016, the EU-28 transport sector accounted for 27% of total greenhouse gas (GHG) emissions, of which 72% are allocated to road transport. To prove that the private owned vehicle is still the favorite means of transportation in many European countries, cars account for 44% of road transport emissions. The systematic and massive use of the private vehicle has repercussions at various levels. There are too many cars circulating within cities, making road management and parking management challenging tasks. Regarding public health, in addition to the respiratory problems caused by air pollution, we are witnessing the decline in the quality of life in urban centers, especially affecting anxiety and stress rates related to feeling overcrowded (Mackett 2013). To reverse this phenomenon, the European Union (EU) established the goal of reducing GHG emissions from transport by 60% by 2050 and has set several intermediate targets to monitor compliance and evaluate the implementation of sustainable methods for passenger mobility (European Environment Agency 2018). Thus, sustainable mobility has become a top priority for the EU countries and, with this, the rehabilitation of transport systems should be based on the following pillars: "efficiency of vehicles, through new engines, new materials and new concepts; greener use of energy by means of new fuels and new propulsion systems, better use of networks and safer and more reliable operation through information and communication systems" (European Commission 2011, p. 8).

Within Europe, it is commonplace that passenger transport belongs to the public sector and services are commonly assigned by concessions which, in market terms, results in almost complete control by the incumbent operator. The lack of competition decreases the need to innovate and since it is a public service, the absence of customer-oriented practices does not stimulate a mindset focused on offering improvement which, in turn, is common in highly competitive business environments (Nunes et al. 2014, p. 581). Nonetheless, tendencies show that regarding the third pillar set by the EC it is expected that innovation will not only be driven by vehicles and the generation/ consumption of energy, but it will also be influenced by the information available on transport networks and communication between passengers and service providers. Based on this argument, it is perceived that the medium-term future involves a strong investment in the public transport sector as a sustainable solution to reverse the current cycle of a “hyper-carbonic” economy.

Highly populated urban areas will evolve to a seamless and multimodal network of services that combine high quality public transport services and private car-sharing initiatives linked to autonomous fleets (McKerracher et al. 2016). The implementation of such measures is under the responsibility of the Member States so each country must apply appropriate national actions to comply with the targets agreed at European level (European Commission 2011, p. 8). There are several initiatives which would motivate people to leave the car at home, such as increasing the price of fuel and parking fees in urban areas, or taxing car circulation on public roads. However, these methods are not popular with the public and instead of motivating the population to choose more sustainable alternatives it changes behaviours by increasing the prices. Many strategies acknowledge that to compete with the perceived benefits of the car it is necessary to create and promote appealing alternatives that satisfy individual needs while improving the overall sustainability of the system.

Over the last few years we have witnessed a growth in the number and quality of mobility services ranging from travel plans (school, work), car sharing (BlaBlaCar, GetAround, Car2Go), bike sharing, flexible transport such as offers based on Demand Responsive Transport (DRT), access to an integrated network of different modes of public transport (Andante card, Oyster card, Whim app), etc. Yet, as shown in Fig. 2, the transition from a mode ownership mindset to a perspective of multimodal access and sharing is linked to sustainability principles and cost reduction.

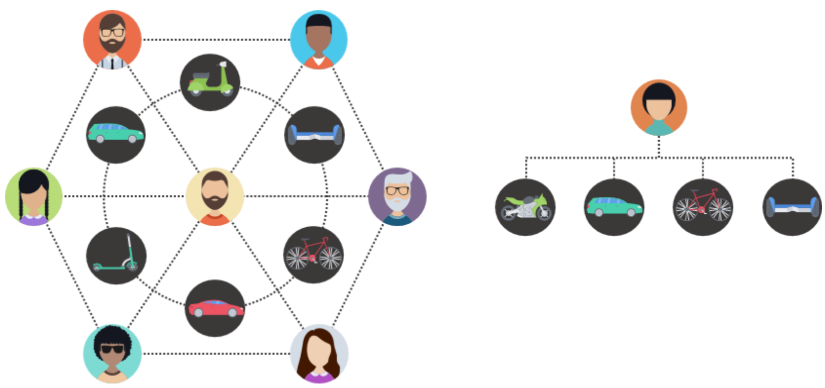


Figure 2 - Shared versus ownership perspective

A new societal and business paradigm is linked to technology evolution. This allows individuals to work remotely and to communicate freely and conveniently to any part of the world (Mackett 2013). By accepting this new standard, service providers can enhance their offerings and meet the mobility needs of a more demanding and connected population, while aiming for environmental sustainability and economic viability. Reduction of operating costs can be associated with providing better services based on value co-creation with the passenger, since this interaction generates valuable data. These will be mentioned in chapter 4.

As society evolves and connectivity levels rise, the development of Information and Communications Technologies (ICT) enables the emergence of new platforms that satisfy specific needs. Access to real-time information and being permanently on-line proves this socio-technological phenomenon, which translates into more demanding customers and consequently the creation of on-demand services. The urban passenger transport sector feels the urge to combine "faster, cleaner, safer, more efficient and customized" integrated solutions for users (Corwin and Pankratz 2017, p. 2). Thus, emerges the concept of Mobility as a Service (MaaS) that advocates for the acquisition of mobility services based on users' needs and consumption patterns rather than transport mode offering. Business models that adopt this concept allow users to access an integrated and seamless offer of various transport modes by creating a platform that conducts several tasks ranging from trip planning to the payment of the service as a whole.

Since real-time information represents a key factor of MaaS, platforms (such as Google Maps, Moovit, Transit) usually display information on the transport network containing the available routes, schedules, times of arrival, etc. Purchasing a ticket can be based on a pay-as-you-go system, ideal for tourists or sporadic users of the network, or through packages that serve the daily mobility needs of commuters (Kamargianni et al. 2016, p. 3296). The perception of trip changes; rather than each stage corresponding to a mode of transport it integrates all the modes used to move from A to B. The emergence of new platforms that offer integrated door-to-door mobility solutions have been well received by the population and the awareness of integration and continuity of services (seamless), explicit in the MaaS concept, imply three important aspects (Kamargianni et al. 2016, p. 3296):

- **Ticket integration and payments**: allowing access to different modes of transport using only one card/ ticket and making payment a single service;
- **Mobility packages**: enabling the purchase of the service in a prepaid system containing a combination of offers and a defined value taking into account limits of distance or time of use;
- **Integration of ICT**: existence of a single application/ platform that provides information on the entire urban transport network.

Figure 3 presents a framework for MaaS that covers a set of aspects ranging from vehicle availability, connectivity, e-payments, personalized services supported by real time information and their influence on other sectors (health, education, governance).

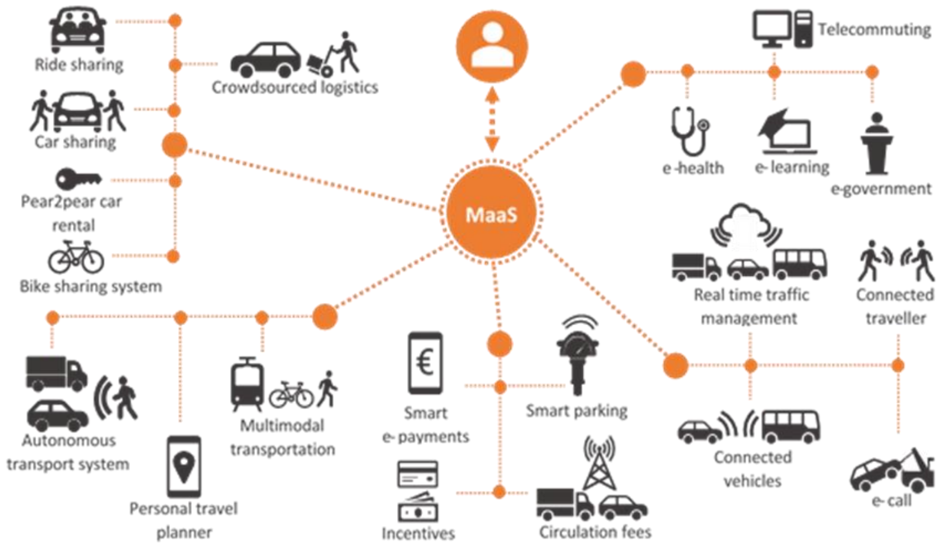


Figure 3 - Mobility as a Service (MaaS) - adapted from Gleave (2017)

Mobility services require the intervention of various entities and certain infrastructure conditions. Connectivity is a key factor to successfully enable the circulation of information and communication between peers and service providers. However, the protection of data must be ensured since it is constantly and freely updated within the network. Remote payment systems must be secure so that customers can use this functionality safely. Goodall et al. (2017) enumerates the panoply of stakeholders responsible for successful rehabilitation of the transport system: government entities able to manage city mobility, telecommunication operators, banks to process payments, transport operators, technology companies to manage and add value to the information generated by the network, and local authorities responsible for monitoring the system.

Many solutions presented in the market arose from initiatives of technological companies (Uber, Taxify, BlaBlaCar, Whim). By using the Smartphone as a channel, the solutions promote communication between the service provider and the end user through the most personal device currently used. Thus, it is possible to personalize a service that, in theory, would include none or few customized features by adding value to the information generated by the network. The concept of Internet of Things (IoT) applied to urban mobility empowers the generation of intelligent systems that facilitate the acquisition, payment and access to public transport. The aggregation of updated information from different operators supports the notion of multimodality and creates a virtual interface for different modes of transport to be accessed (Corwin and Pankratz 2017, p. 8). Tech firms can leverage the benefits emerging from these circumstances by extracting data from the network, deploying data analytics and create valuable knowledge by enhancing its capabilities regarding machine learning. The infrastructure will increasingly include sensors to monitor network performance and provide a wide spread of internet access to enable connectivity, which also supports the development of accurate location-based systems, responsible for optimizing pay-as-you-go dynamics

(McKerracher et al. 2016). Also, by acknowledging the Smartphone as a sensor capable of monitoring passenger behaviour it is possible to provide an end-to-end, connected travel experience. This means that the information provided is relevant on a personal level. In this sense, it will be possible to return control over personal mobility to the passengers through access to up-to-date and optimized information about the whole network.

2.1.2. Urban Mobility in benchmark cities

This section encompasses the analysis of several key mobility parameters according to benchmark cities. This exercise intends to reflect on the current state of mobility and future implementations (Dixon et al. 2019). Cities such as Amsterdam and Copenhagen are top leaders regarding urban mobility practices and were selected due to their similarity to Porto considering size and population. Lisbon is the largest city in Portugal, and it is the natural comparison to Porto for national purposes. Hong Kong and London represent global leaders and their presence in this exercise is useful to understand the best practices encompassing such large areas and great investments.

Table 1 analyses good practices (GP) and to improve (TI) situations regarding infrastructure, policies, technological innovation and public transport service. A mobility system encompasses an upgraded infrastructure that benefits soft modes such as pedestrian walkways and bike lanes, the rise of electrical vehicles (EVs) demands investments in distribution of charging points and physical interfaces between modes to promote multimodality. Since municipalities are relevant stakeholders in mobility matters it is important to reflect on their openness and will to collaborate with the private sector. These should also support open data platforms and establish regulations to facilitate innovation and technological deployment. Technology is influencing the way people move. The implementation and adoption of technologies that enable the circulation of data improve the overall performance of the system. Finally, public transport represents a key factor to achieve sustainability in the short/medium term, thus a high service delivery is essential.

Table 1 - City mobility performance - based on 2019 Deloitte city mobility index by Dixon et al. (2019)

		Infrastructure	Policies	Public transport service	Tech innovation
Amsterdam	GP	extensive bike lane network; increasing charging points for EVs	promotion of shared mobility; collaboration with private firms; EVs incentives; AVs regulation	reliable transport network; PT is reachable within 1km; DF system; variety of options (high multimodality)	open data platform to enable data-based innovation across sectors; data-driven ITS; application of self-driving tech across different modes
	TI	standardize IS requirements for private bike players; improve parking	alternative revenue to improve transport affordability; improve policies around network layout to avoid inefficiencies	expensive fares - not accessible for low income families	
Copenhagen	GP	interfaces between parking and stations; BF city; increasing charging points for EVs	municipal EVs; promotion of open data and digital solutions	extensive intermodal network; good last-mile transport connectivity (car-sharing); affordable service; high customer satisfaction; variety of ticketing schemes with unlimited use of PT network; DF system	ITS to improve congestion
	TI	expand bike lanes due to congestion	High nitrogen levels; redesign bus routes; ensure road traffic while prioritizing bikes		establish centralized regional data hubs for smart city data
Hong Kong	GP	PT nodes closer to relevant areas (offices, houses); PT expansion	electronic road pricing; municipal EVs; EVs incentives; private-public rail property to generate additional income	contactless payments moving towards mobile e-payments; barrier-free PT facilities; tax rebates for PT expenses; integration of private-public bus operators to improve offer	AI to improve punctuality and predictive maintenance
	TI	congestion; smart parking around central areas	lack of regulation to promote shared mobility; few policies promoting active transportation	improve access for low income families	late adoption of modern technology
Lisbon	GP	creation of pedestrian areas and bike lanes; increasing charging points for EVs; parking interfaces with PT	promote active transport; municipal EVs; openness to test new technologies; promotion of PT green solutions; single pass in the MAL	convenient payment integration between bus and metro; reliable system; high customer satisfaction; increasing fleet; PT wi-fi; electric public bikes; parking fees included in monthly PT packages	expand the use of data analytics to promote multimodality; open data portal to enable smart city initiatives
	TI	narrow, hilly roads, inadequate signage and limited parking spaces	simplify legal structure to promote alternative business models; collaborate with private sector to increase PT coverage; absence of clear regulatory stance for AVs testing	not all stations are DF; high theft rates in PT; low universal coverage of the network and low accessibility	
London	GP	identification of bike lanes to be created	collaboration with the private sector to create innovative solutions; advanced regulatory environment; promotion of active transportation and sustainability	contactless payments across the network	high tech solutions to improve road safety; high coverage of open-data and real-time traffic analysis tools
	TI		high transportation costs across the sector (everything is expensive); too many authorities for road maintenance (difficult decision-making)	improve reliability; expensive fares; many stations are not DF; crowded system; optimize transport capacity; improve multimodal integration for first and last-mile options	solutions for demand management schemes to balance supply and demand
Porto	GP	interfaces between metro, bus and rail;	promotion of active transportation; free PT access for some age groups; single pass in the MAP	mobile e-payment solutions (advanced algorithms); integrated ticketing solutions across the network; reliable and affordable system;	use of real time information for traffic management and passenger information
	TI	narrow, hilly roads to build bike lanes;	enhance collaboration with the private sector to create innovative solutions	low coverage in outside areas; not all stations and fleets are DF; improve PT	promote open data platforms to access relevant information of PT

GP: Good Practices; TI: To Improve; PT: Public Transport; E(A)V: Electric (Autonomous) Vehicle; ITS: Intelligent Transport System; DF: Disabled-Friendly; IS: Infrastructure; BF: Bike-Friendly

2.2. Passenger information on public transport

Regarding the statement of "better use of networks and safer and more reliable operation through information and communication systems" (European Commission 2011, p. 8) it is clear that passenger information plays a fundamental role in attracting people to public transport. Intelligent Transport Systems (ITS) include a series of subsystems that enable advanced control of the network through the implementation of both technical and technological solutions. The goal is to improve comfort, security, and reliability on the public transport networks. PIS (Passenger Information System) is included in the ITS and this section will analyse the communication channels and available information. A short reflection on its aspects and implications will be presented after.

2.2.1. Available information and communication channels

For many years, information has been distributed in printed versions both at stops and on flyers that contained static information regarding network routes and stop timetables. However, technological developments allowed the creation of devices capable of supporting information in digital format that are being constantly updated, thus combining scheduled information with real-time information. Nunes et al. (2014) reflect on the needs concerning passenger information and such demand combines information about different travel alternatives and trip-related aspects such as comfort, convenience and privacy. The four main types of information required by the passenger are illustrated in Fig. 4 (Sarkar et al. 2018).

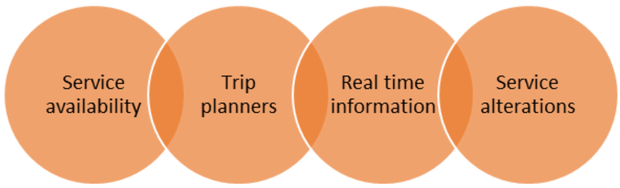
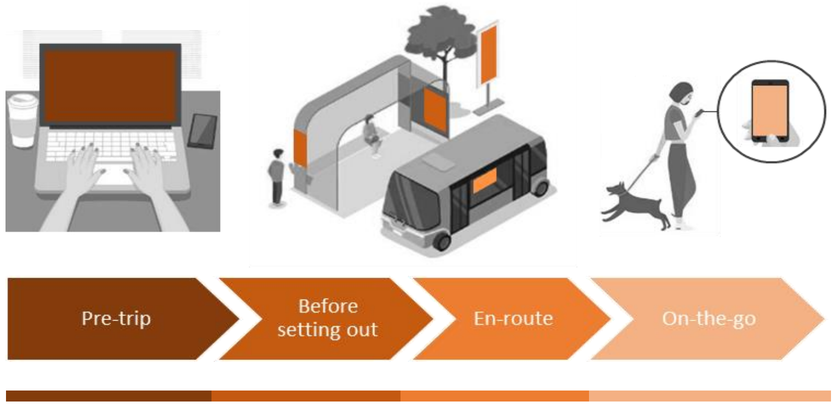


Figure 4 - Strands of information - retrieved from Sarkar et al. (2018)

A transport network is not homogeneous regarding its service offerings. For example, throughout the day trip frequencies change according to demand fluctuations for a given line. Also, services are also more available and diversified within central areas when compared to less populated areas. Thus, once the service itself changes according to the location and time of day, it is expected that the communication channels respond to the demand in a viable way by including the necessary information according to the phase of the trip. Figure 5 supports this statement by demonstrating the phase of the trip and respective channels and required information.



At this phase, the user needs to know the mobility services available (metro, train, bus, carsharing, bikesharing) and respective destinations, timetables and costs to allow planning the trip ahead based on the best alternatives;	Destination and arrival time of the next buses (minutes); timetables, tariffs, network map, interfaces available; other warnings such as current travel disruptions	Minutes to next stop; next stops and minutes to arrive; minutes until the destination; current time; connecting services (interfaces); other warnings (delays, traffic jams, strikes)	Route until destination; exact location of stops; real time info about the planned trip; arrival time of the bus intended to take; delays and other travel conditions; alternatives if requested; all the tailored information related to favorites; city map; points of interest; bus capacity; ticket validation and e-payment

Figure 5 - Required information per channel and trip phase

Apart from knowing the available operators, routes, timetables and tariffs, users benefit from trip planning platforms that, through advanced algorithms, can generate a series of trip alternatives from which the user can choose the most suitable one. This pre-planning enables users to manage their time better and know the expected duration of the trip, price and so on. Users can also profit from real time information in a sense that it is possible to access information on road congestion, accidents and delays. More than knowing the expected time of the bus, users want to know the exact time it arrives, since delays and excessive time on board happen quite frequently. By having the opportunity to choose, users take control over their mobility choices and this contributes to more satisfied and loyal customers. On the other hand, they also want to be notified when service changes occur, whether they are predicted or not. When these warnings are directly sent to Smartphones, users are updated on the different alternatives available in case of unforeseen events (Nunes et al. 2014, p. 582). In addition, there are non-regular users of the transport network which might question the reliability of the service and feel unfamiliar with it which directly affects the overall experience of the service. This argument evidences the importance of reliable information in the perception of the quality of the service and indicates that, primarily, users require reliable arrival times and destinations of each route. Studies have also shown that perceived waiting times are greater in systems lacking real-time information (Alves et al. 2012, p. 470).

Nonetheless and as mentioned before, information can be static (predicted) or provided in real time (Šarić et al. 2012, p. 244):

- **Static information** refers to available service providers and respective routes, destinations, timetables, tariffs and ticketing system.

- **Real time information** enables access to accurate arrival times, planning trips according to the real status of the network and estimated times of arrival (ETA), vehicle capacity, and provide immediate alternatives when unpredicted events occur. It can also inform on other aspects of mobility such as road conditions, weather forecast, parking places available, traffic queues, tourist information, among others.

To support any type of information, a communication channel is needed. There are many kinds of communication channels; some are as simple as a printed flyer and others incorporate high technology such as LED displays that require a vast technical and technological infrastructure. There are also greener technologies like the e-paper display which is off-grid, solar-powered and consumes minimal energy.

With the lack of a formal characterization that would serve the purpose of this project, the presentation and classification of the various communication channels within the public transport sector will be based on three principles considered relevant by the author and presented in Fig. 6. Access refers to the place or situation in which the user accesses the information and it is related to the trip phase in which the channel will be most useful. The second parameter has to do with the type of information displayed in a given channel: static refers to information that is occasionally updated and it is frequently accessed in advance to plan the trip; real time information relies on digital devices and AVL (Automatic Vehicle Location) since the real position of the vehicles is constantly updated to present the latest status of the network. Lastly, communication depends on the available channels: one-way communication happens when the channel only displays information issued by the operator without the user interacting with the system; two-way communication refers to higher degree of communication since the passenger can access information upon request and create input to the system by interacting with it.

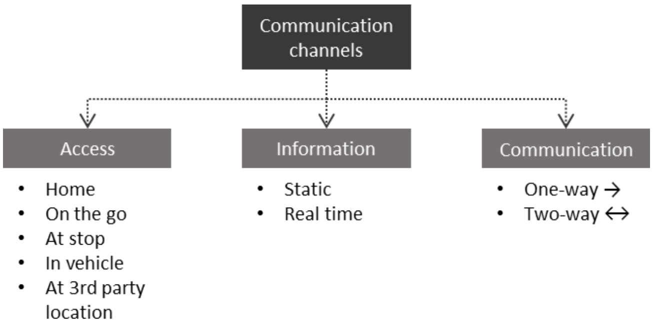


Figure 6 - Communication channels classification

Table 2 presents the channels according to the previous classification (access, information and communication). This table presents the identification of the communication channels available, what types of information and communication they support, and the content they display in order to facilitate the comprehension of the differences and similarities between them.

Table 2 - Characterization of the available channels and displayed information

Channel	Icon	Information	Communication	Displayed content
Display at 3rd party location		Real time	→	Multimodal options – routes, destinations, service providers, minutes to arrival/ departure, other warnings
At stop display		Real time	→	Available lines, bus number, destination, minutes to arrival, other warnings
In vehicle display		Real time	→	Next stops and respective minutes to arrival, connections at the interfaces ahead, other warnings
Touch display		Static	↔	Available routes and lines, purchase/ recharge tickets
At stop paperboard		Static	→	Available routes and respective destination and timetable, network map, available interfaces and connections, tariffs, contacts
Other printed material		Static	→	Timetables, maps, tariffs, promotions
Website		Both	↔	Static: available services (routes and stops, timetables, tariffs, maps), surveys RT: trip planners, service alterations, news, schedule trip
Mobile application		Both	↔	Static: operators' available services (timetables, routes, maps, stops), POI RT: trip planners, service alterations, multimodal options, next arrivals, ticket validation, e-payments, location-based info, schedule trip
Social media		Real time	↔	Service alterations/ interruptions, forum discussion
Phone call and SMS		Both	↔	Static: automatic answer - available services (routes and stops, timetables, tariffs) RT: next arrivals, service alterations, schedule trip
Audio warnings		Real time	→	Next arrivals/ departures and respective destinations, service alterations, other warnings
Word to mouth		Both	↔	Peer-to-peer or ask an employee: any kind of information

2.2.2. Aspects and implications of advanced PIS

According to Sarkar and Jain (2018) the implementation of an ITS prioritizes public transport, particularly in heavy road traffic, to facilitate a smooth circulation and compliance with schedules and estimated travel times. Therefore, a reliable PIS improves the perceived quality of the service by displaying real-time information to the passenger at the different stages of the service interaction. The integration of information provided by the different service operators facilitates service transitions between them at the available interfaces in a seamless and integrated way. The constant monitoring of the network enables dealing with unforeseen events or emergencies that may occur and thus minimize the time to resolve these situations. This monitoring allows the optimization of routes, schedules and planning through the rational and efficient use of the available resources.

An advanced PIS contributes to efficient travel and increases overall confidence in public transport (Isa et al. 2013). In this sense, a PIS acts as a "combination of people, hardware, software, communication devices, network and data resources that processes data (storing, retrieving, transforming information) for a specific purpose" of informing, instructing or warning the passenger. Nonetheless, passenger information provision presents some issues that are difficult to tackle due to the complexity of the technology involved, diversity of channels which are preferred by different types of passengers and the general availability of data. For instance, Fig. 7 shows there are channels that are useful in the same phase and display, more or less, the same type of information.

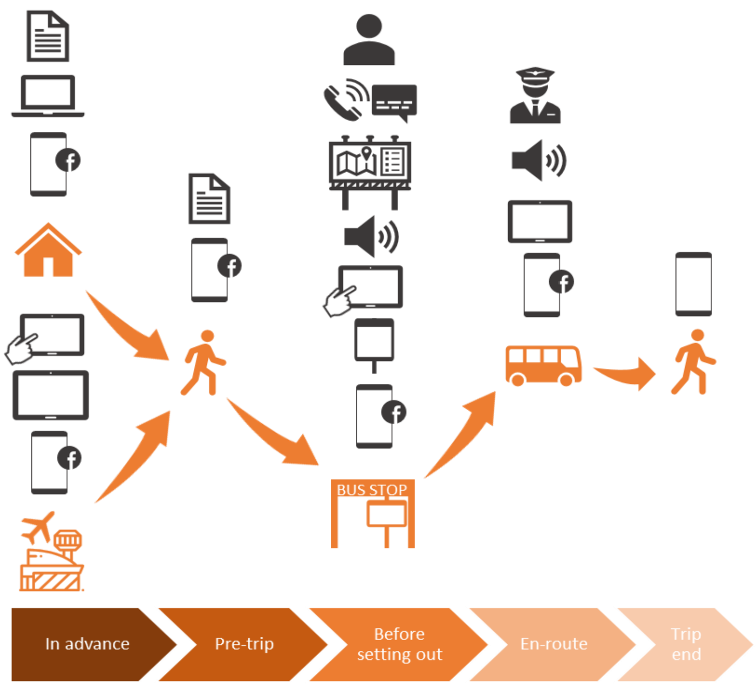


Figure 7 - Available channels for the different accesses and trip phases

When there are different channels presenting the same type of information it can lead to redundancy and lack of accuracy. This situation may lead to the following questions:

Why is it that the most advanced channels have not yet completely replaced the outdated ones?

The public transport system serves a very wide audience because it supplies passengers of all ages, genders, backgrounds, qualifications, occupations and technological aptitudes, etc. The option of choosing one channel over another reflects a personal choice that is influenced by the combination of factors indicated above. As typically happens when adopting innovations, transitioning from one habitual channel to a more advanced one happens in different ways with different people. By collecting the principles of the diffusion of innovation theory and its different adoption rates (Rogers 1983) it is possible to understand, by analogy, the prevalence of some communication channels that are outdated considering the quality of the most technological channels available today and the information provided by them. According to E. M. Rogers (1983) there are innovators, early adopters, early majority, late majority and laggards. There are several factors that contribute to the differences between rates of adoption: price, technical features, time of adoption, and perceived value. These adopter categories will be explored in section 2.5 but the key point refers to the permanence of less advanced channels which still serve a part of the population that includes the late majority and laggards.

Regarding actual content, gathering data can be resource intensive, fallible, hard to manage, and share due to the numerous data generators (operators). Its accuracy strongly depends on advanced algorithms that are not infallible. Apart from the numerous communication channels available and available data, there is still a struggle in providing the right information, through the right channel, at the right time, to the right passenger. This interaction must be useful, and information should be presented when most needed with high levels of accuracy and fast response rates (Sarkar and Jain 2018).

Is it worth investing in real time passenger information (RTPI)?

Studies have considered the importance of RTPI and, despite the difficulty in establishing tangible financial profits generated by information systems, they do promote the use of public transport and contribute to more satisfied customers. The growing investment in real time information systems represents an acknowledgment that the public transport sector is not completely reliable in terms of compliance with scheduled information. This feature enables passengers to conduct trips with confidence and find alternatives easily in the case of any disruption, helping them to manage their time efficiently (Ferris et al. 2010).

The effective dissemination of real time information relies on AVL and it is dependent on a complex structure that requires hardware to be installed in every bus within the network and software that enables communication between the vehicles and the central centre. AVL can include GPS and other technologies such as beacons (hardware transmitters). This system collects information on the operation of the network and when compared to the scheduled information it predicts how the network will perform in a given time frame. This information can include more relevant information by combining data with the effect of road congestion or adverse weather conditions (Sarkar et al. 2018).

2.3. The role of the Smartphone

The Smartphone is expected to enable LBS (Location Based Services) due to its hardware and software characteristics (Šarić et al. 2012, p. 246). This study predicts that Smartphones will become the main tool to display passenger information in the near future. The widespread use of the Smartphone will result in more complex reconfiguration of personal schedules as well as travel needs and patterns. However, Aguilera and Boutueil (2018) defend the notion that Smartphones and access to information will not influence modal choice. Instead, Smartphones will optimize traveling, reduce financial costs for both users and service providers and promote multimodal practices. According to Lyons (2018), smart mobility encompasses a broader sense of moving around urban spaces. Instead of just requiring a mode of transport, the mobility experience includes several factors such as connectivity, affordability and effectiveness, attractiveness and sustainability. The research reflected on the influence of Smartphones on these factors. Regarding connectivity, it reduces or mitigates the need for physical connectivity (physical travel from A to B) as it allows users to access shopping services, banks, music, books and other media through the mobile phone. In terms of public transport, Smartphones optimize physical connectivity by providing real-time information about the network. Although the Smartphone is not used by 100% of the population, these devices support location-based systems that, by downloading an app (for instance), allow access to mobility platforms and payment for the services considering the actual use of information technologies.

By itself, the Smartphone makes the mobility experience more interesting for passengers by being interactive and enabling the integration of several platforms that make life easier for users. However, different users have different perceptions of service attractiveness so, the Smartphone represents a tool that allows customization and tailors services to specific needs while creating value from unique user interactions. The use of the Smartphone mitigates the need for cards/paper tickets and other resources once needed to access transport services. It is also no longer necessary to change static information at each stop whenever periodic service changes occur (Lyons 2018, p. 9).

Figure 8 shows an overview of the impact of the Smartphone in urban mobility and personal mobility patterns. It concludes that real time information displayed in personal devices will likely solve some transport-related challenges. The authors Aguilera and Boutueil (2018) reflect on the importance of the Smartphone, considering its characteristics, to perform daily tasks to facilitate commuting. By adding real time information to this device, it will contribute to perform daily activities remotely allowing the user to manage time in a more efficient way. Through the integration of multimodal information, geolocation, and e-payments it is possible to provide a seamless mobility experience across the network. Also, the circulation of data and information will boost regulation. By including these aspects into a user-friendly app, it promotes the use of public transports and contribute to a greener and more efficient society.

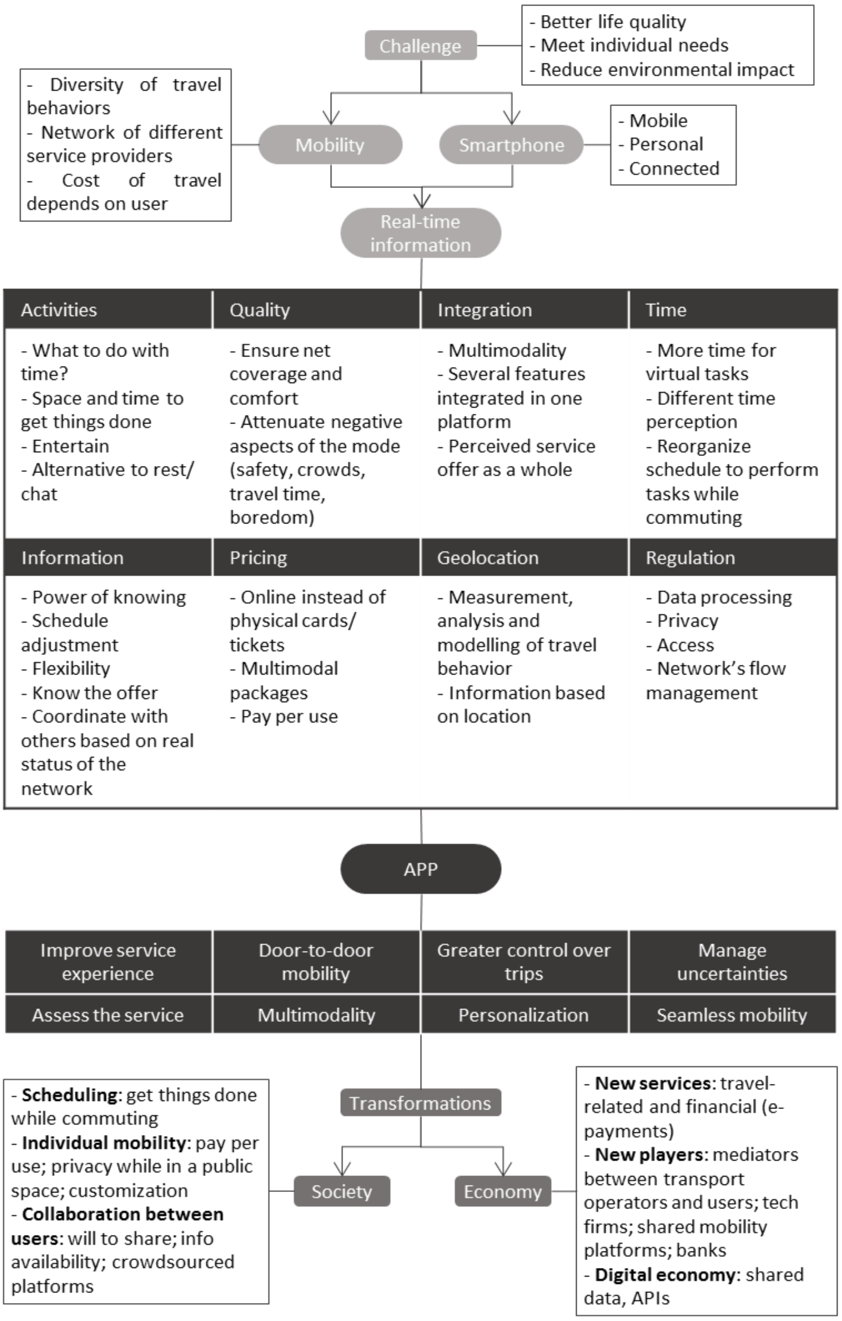


Figure 8 - Urban Mobility and the Smartphone - summarized from Aguilera and Boutueil (2018)

Since the Smartphone allows a two-way communication it can increase the value of the operator-passenger interaction by providing a personalized platform where data is exchanged and not merely delivered. According to Nunes et al. (2014), the increasing access to Smartphones within public transportation users represents an opportunity to associate them to the service creation and delivery process. The idea is to improve customer experience and operational cost reduction. While the interaction with the service deliverer allows users to access real time information on their personal device, on the other hand, by interacting with the system, users are creating relevant data to the service provider. When structured and managed properly, the information retrieved from customer usage of the service enables the understanding of user experience and overall performance of the service. The value for the customer lies in the fact that the information received is related to the individual usability of the transportation service and mobility habits. In this way, users can assess a series of alternatives and choose according to which bests suits their needs. (Nunes et al. 2014, p. 578)

When thinking in a macro perspective that includes the principles illustrated in Fig. 9, the more passengers generating data within the network, the more distributed the system view is, as it combines unique user experiences and, regarding cost reduction, this approach mitigates the need to invest in control systems.

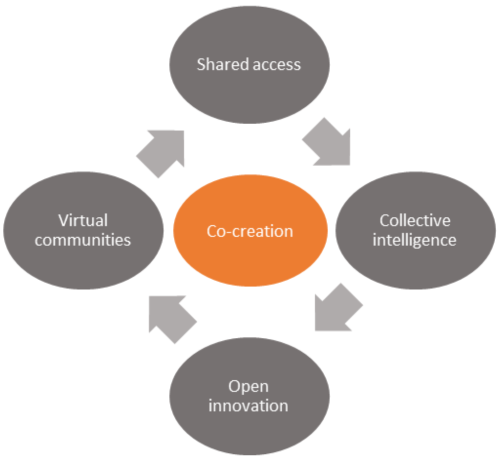


Figure 9 - Co-creation framework - retrieved from Zwass (2010)

This new level of customer interaction is uninterrupted, digital and enables the free monitoring of users' opinions. We are currently witnessing a shift regarding how services are designed and provided to the client. Increasingly, organizations are engaging with the customer based on a constructive mindset, for instance, relevant users are testing beta versions, crowdsourcing is used as a tool to collect data and open source software is becoming a popular practice within tech firms. Nunes et al (2014) evidence the introduction of service-dominant logic in the public transportation sector. The notion of using a mode of transportation such as the bus or metro vanishes as the level of customer involvement with the service delivery arises. This co-creation phenomena within the public sector leads companies to evolve to an integrated perspective of delivering mobility services as one combination of different modes which share a common goal of getting passengers from A to B, seamlessly (Nunes et al. 2014, p. 579).

A clever strategy to attract new passengers and retain the ones currently using public transport includes providing real time information which is relevant to each individual. Service personalization regarding urban mobility will improve user experience since it becomes flexible and adaptable to door-to-door needs (Nunes et al. 2014, p. 581). Users who engage with the service enhancement should be encouraged and rewarded for their contribution (Nunes et al. 2014, p. 580).

2.4. App specification language

UML stands for Unified Modelling Language (Watson 2008) and it was used as a formal language for the specification of the future App in terms of user interaction as a simple way of defining and documenting the required features.

UML emerged in the mid-1990s due to the conflicts regarding definitions and nomenclatures in the modelling area within the software engineering field. Before UML, there were different notations that were incompatible and adopted depending on personal preferences that did not follow a common pattern. “Many (notations) only allowed sketching of software designs, lacking facilities for checking the diagrams’ internal consistency or automatically processing the information they held” (Watson 2008). The concept emerged from the cooperation between Ivar Jacobson (OOSE – Object Oriented Software Engineering), Grady Booch (The Booch Method) and James Rumbaugh (OMT – Object Modelling Technique) who intended to create a unique modelling pattern. Later, in 2000, it was approved as standard by the OMG (Object Management Group) and has been a “language for graphical modelling of complex systems that include hardware, software, information, processes, personnel, and facilities” (Watson 2008) ever since. Nowadays, it covers more than software design and it is applied to non-software areas (systems engineering and business).

Through concepts, objects, symbols and diagrams, this language provides a simple but objective and functional documentation that allows the understanding of the system and the interactions within it. UML ensures greater clarity and objectivity in the execution of each phase of the project (definition, development, homologation, distribution, use, and maintenance). As explained before, it is a standard language for visualization, specification, construction and documentation of an application or software project and aims to increase productivity, optimize the steps involved in developing a system, thus increasing the overall quality of the product to be implemented. This language allows the logical visualization of the whole process to facilitate its real implementation (Gustavo 2009).

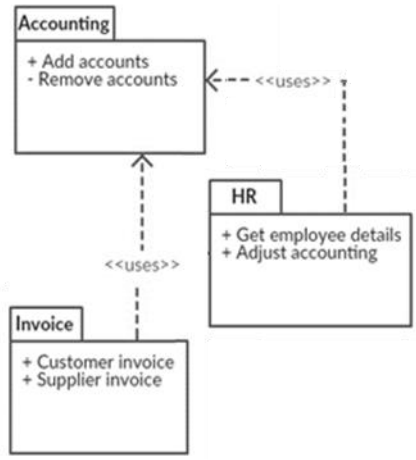
Table 3 displays the characteristics of the two basic categories of diagrams: structure diagrams and behaviour diagrams. The purpose of the structure diagrams is to show the static structure of the system to be modelled. On the other hand, behavioural diagrams show the dynamic behaviour between objects in the system.

Table 3 - Types of UML diagrams and definitions - retrieved from SmartDraw 2019

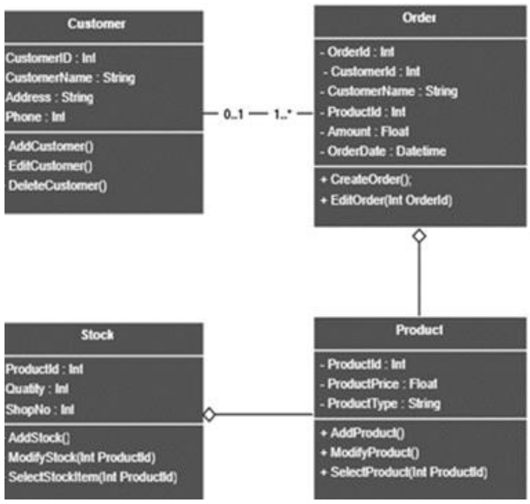
Structural diagrams	
Class diagram	It is the pillar of object-oriented methods and defines the static structure of a system. It maps the structure by clearly displaying the various classes, attributes, operations, and relationships between objects.
Package diagram	Represents the sub-systems encompassed by a system and organizes its elements into related packages to minimize dependencies between them.
Object diagram	Depicts (at a particular time) software objects and their interrelationships which can be used to test class diagrams for accuracy.
Component diagram	Shows the structural relationship between the software system and its elements while organizing the physical software components (source code and executables)
Composite structure diagram	Defines relationships between elements by describing the internal collaboration of classes, interfaces, or components to specify a functionality.
Deployment diagram	Describes hardware and software components and their interaction with other processing support elements and respective connections.
Behavioural diagrams	
Activity diagram	Shows the flow of control from one activity to another and it is used to model dynamic aspects of the system. Activity is an operation that changes the state of the system.
Sequence diagram	Represents the sequence of processes, more specifically, of messages exchanged between objects. Facilitates the understanding of the overall sequence of behaviour.
Use case diagram	Represents the set of high-level behaviours that the system must perform (functionalities) for a particular actor.
State diagram	Represents the state or situation where an object is (in the course of executing the processes of a system) in response to an external stimulus.
Communication diagram	Displays an interaction, consisting of a set of objects and their relationships, including messages that can be exchanged between them.
Interaction overview diagram	It is the combination of activity and sequence diagrams and represents the sending or receiving of data between an actor and a use case.
Timing diagram	It presents the behaviour of objects and their interaction on a time scale, focusing on the conditions that change over that time period.

Figure 10 presents some examples of the diagrams found useful for this project.

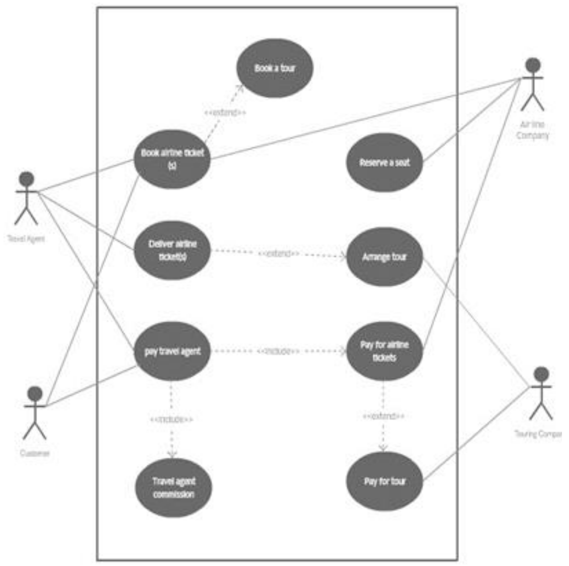
Package diagram



Class diagram



Use case diagram



Sequence diagram

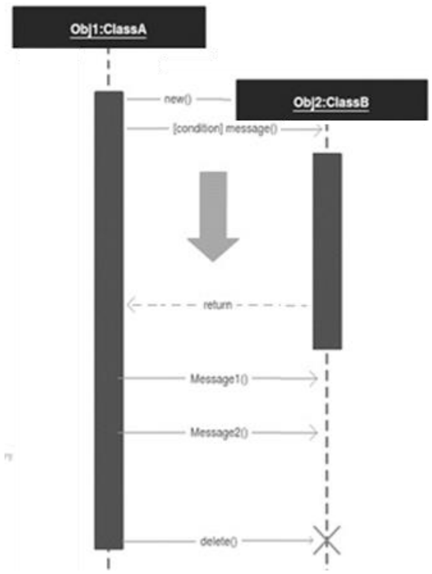


Figure 10 - Examples of UML diagrams - retrieved from Nishadha (30/04/2019)

2.5. Innovation and Business

This section presents one business theory and two business strategies that, when combined, might create an interesting framework for the proposed project regarding entry into the market.

As mentioned previously, the diffusion of innovation theory emerged to explain the dissemination of a certain idea or product across a social system. The theory was developed by E. M. Rogers and reflects on an idea or product as an innovation compared to what was previously established. Since it is a social theory it encompasses the different rates of adoption related to different social groups. Thus, people who adopt innovations faster have different characteristics and value different aspects regarding the idea, product or behaviour. The different groups of innovation adopters are presented in table 4.

Table 4 - Adopter categories - based on Rogers (1983)

	Characteristics	**Values**
Innovators	The first to adopt; interested in newness; risk takers; easy to appeal; tech interested; visionaries;	Technicalities of the product; do not care about the price; will test everything that is new
Early adopters	Opinion leaders; will to change; aware of new opportunities; no need to convince them to change; pragmatic	Pay attention to the service embedded in the product and other general aspects
Early majority	No leaders of opinion; adopt faster than the common person; require evidence of success	focus on the service provided and price
Late majority	Sceptics; only try after the majority; require number of people already using the innovation effectively	dependent on the price and are more likely to buy products from market leaders and well-established products
Laggards	Conservative; do not like to change; require statistics, fear appeals; and social pressure	do not care about the technicalities and focus on the final goal they want to achieve; buy the cheapest option that satisfies their needs

According to Rogers (1983), there are several aspects on which people rely to assess an innovation and good rates of these aspects result in higher rates of innovation adoption:

- **Relative advantage** – the value of the innovation in relation to its substitutes
- **Compatibility** – if the innovation is consistent with people's values
- **Complexity** – ease of usage or understanding the innovation
- **Trialability** – the ease of testing the product or service
- **Observability** – if the results of it are visualized by others

In the matter of diffusion, time is difficult to be measured. However, there are several stages between the first contact until effective adoption/rejection (Rogers 1983): knowledge of the opportunity to adopt, persuasion, decision to adopt, implementation (testing) and confirmation of the adoption.

Behaviours regarding mobility patterns depend on a set of individual characteristics which are strongly linked to social norms and for this reason the diffusion of innovation theory will be helpful to determine a business model for the new concept of the operator-passenger interaction.

Kim and Mauborgne (2015), the creators of Blue Ocean Strategy (BOS), propose that to create differentiating products the competition must become irrelevant by creating value outside the boundaries of a saturated market (red ocean). To achieve this differentiation, the company must adopt low-cost measures to create and launch a product created to meet a demand that had not been met previously, thus creating a new competition-free market. This theory argues that in red ocean markets the objective is to outperform competitors' therefore, the profit margins are smaller, and the allocation of resources is based on this assumption. By creating a new market, the company can focus on creating value from a product that is not a mere commodity, easily imitated by competition, as demand is created and not disputed. There is, therefore, a great opportunity for fast and profitable growth, since the company can easily reach the customer without having the problems of entering the market because this is unknown, and its rules are not yet determined (Kim and Mauborgne 2015). There is clearly a trend of shifting from simple business planning to experimentation and learning therefore, the authors present the six principles of BOS (Kim and Mauborgne 2015):

- **Reconstruct market boundaries**: extend the market to respond to an unknown and unmet demand, where there is no competition
- **Focus on the big picture, not the numbers**: think of a strategy that goes beyond incremental improvements to create innovation from customer value
- **Reach beyond existing demand**: to aim for a more accurate segmentation to satisfy customers by aggregating demand, by perceiving the similarities between non-customers (expanding the blue ocean) and not by creating small niches
- **Get the strategic sequence right**: respect the sequence of utility, price, cost and adoption requirements to realize the risk associated with the idea in a viable way
- **Overcome key organizational hurdles**: leadership guidelines to tackle the organizational risk of shifting towards a blue ocean strategy
- **Build execution into strategy**: experimentation-oriented, motivates people to execute towards blue ocean strategy

Regarding experimentation, Lean Startup (LS) is a business methodology that defends the shortening of product development times and testing them rapidly to quickly verify whether the idea is viable or not. The effectiveness of a business plan is relative and depends on the context so instead of spending a great amount of time elaborating on a complex business plan, this strategy mixes business-hypothesis-driven experimentation, iterative product launches and validated learning to optimize the process. The LS methodology indicates that startups invest their resources in order to create value iteratively for the early adopters of innovation so the company can test various versions at the same time (split test) and reduce the need for major initial investment and the risk of failing or misappropriating some feature that does not provide customer value (Ries 2011). With split tests and iterative development, the company can apply the Build–Measure–Learn loop (Fig. 11) by assessing clients' reactions and behaviours towards the offer.

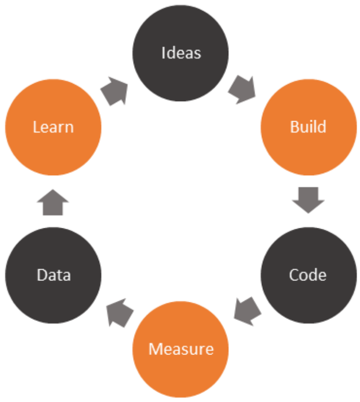


Figure 11 - Build–Measure–Learn loop - adapted from Ries (2011)

As in Lean Manufacturing and Lean Software development, the Lean Startup methodology strives to optimize resources in order to create development practices that create value in the earliest planning phases. For this, customer feedback is most relevant to product development since it mitigates the risk of creating a product that does not meet customer needs. Frequently, a firm cannot rely on a single product to ensure profit. Through a minimum viable product (MVP), which is a "version of a new product which allows a team to collect the maximum amount of validated learning about customers with the least effort" (Ries 2011), it is possible to verify the customer's acceptance and intention to adopt. To verify these phenomena, it is useful to use key performance indicators (KPIs) and continuous deployment (applied to software development) to improve the product iteratively and reduce cycle times. These are closely related to the notion of innovation accounting which focuses on "measuring progress, planning milestones, and prioritizing" (Ries 2011).

2.5.1. Data protection

The EU General Data Protection Regulation 2016/679 (GDPR) aims to unify data privacy laws within Europe, protect EU citizens regarding their private data and restructure organizations' approach towards data privacy. Entities who require personal data to deliver products/ services must establish a legal basis that includes the direct and explicit consent of the individual that allows the collection and processing of personal data in a contractual manner in accordance with the rights of the individual and entity (Article 6). For children under the age of 16, parents must allow the use of their personal data. It is necessary to verify the security requirements under the GDPR (General Data Protection Regulation) in order to protect the legal rights and freedom of the individual. If the data subject does not have a true or free choice or cannot refuse or withdraw consent without being impaired, consent of free will should not be considered.

The same applies when the execution of a contract, including the provision of a service, depends on consent even though consent is not necessary to deliver the service involved. People must be able to withdraw consent regarding the collection and processing of their data as easily as they gave it. The data subject should also be able to access personal data and inquire about its processing and access (Article 15) and may also request its update or final disposal at any time (European Parliament, Council of the European Union 2016). Entities should also assess the risks to the rights of freedom to control processing and implement organizational and technological measures to ensure data safety. In addition, legal data holders must be able to prove compliance with GDPR at any time in order to evaluate the adequacy of the measures implemented and compliance with the legal basis. In order to avoid storing unnecessary personal information, the entity shall minimize the amount of personal data to be processed and access what is strictly necessary (Article 5 (c)) (European Parliament, Council of the European Union 2016).

Entities with more than 250 employees, small and medium-sized enterprises (SMEs) that process data regularly or deal with sensitive personal data must keep records of the processing activity (Article 30) regarding the purpose of processing, category of subjects, personal data involved and categories of recipients. It is necessary to assign a data protection officer (Article 37) if the core business activities of the entity are data processing driven and require regular and systematic large-scale monitoring or deal with data that pose risks to individual freedom or sensitive data/ criminal records. When using the profiling method in data processing it is necessary to inform the users, and to assign a person responsible for monitoring the process. It is also necessary to create alternative non-automatic processing methods such as human intervention. For marketing campaigns, users have the right to refuse direct marketing (European Parliament, Council of the European Union 2016).

The communication with the individual must be clear regarding the processing of data, purpose of the use, period of data storage and who accesses the information. The entity should present itself clearly upon the request for data access. When a company processes data for another company the responsibilities of each party must be listed contractually (European Parliament, Council of the European Union 2016). To enable easy compliance with the established norms in the GDPR it is advised to implement data protection safeguards from the beginning of the development of the service.

2.6. Relevant legal aspects

In this section, two legal aspects that will serve as arguments for this project are mentioned. The first one demonstrates the importance of evaluating customer satisfaction in the transportation sector and, in this sense, it is expected that a solution via Smartphone will be able to frequently collect the user's opinion regarding the service. The second one portrays the importance of data protection as a European directive and allows the investigation of key points of the General Data Protection Regulation (GDPR) since this project presents a digital solution.

2.6.1. Assessment of customer satisfaction in public transport

According to Law no. 52/2015, Lisbon and Porto Transport Authorities are extinct by passing on the responsibility of managing the public passenger transport system to the respective Metropolitan Areas (MAs). Among several competences, MAs are responsible for conducting surveys on mobility patterns according to their geographical area and for publicizing the public passenger transport services. Considering Article 5 of the Law, the State is the responsible authority for public passenger transport services operated not only, but also, by internal operators including Metro do Porto, Sociedade de Transportes Coletivos do Porto (STCP), the Company Carris, the Metropolitan of Lisbon, among others.

It is the responsibility of municipalities to manage passenger transport services operating within their respective territories. Intermunicipal communities, which include the Metropolitan Area of Porto (MAP) and the Metropolitan Area of Lisbon (MAL), are responsible for the public transport of passengers if these operate in an intermunicipal level and involve municipalities that cover a significant part of the community.

Regarding meeting the mobility needs of the population, by December 3rd, 2019, the minimum levels of services' implementation must be measured as well as the resources allocated to their financing. The Law does not clarify who is responsible for this last point, but, according to several Portuguese Norms (PN) ("PN 4493: 2010 - Public passenger transport. Route of urban buses. PN 4475/2008 - Public passenger transport, Metro network, features and service provision" included in "PN EN 13816: 2003 - Transport - Logistics and Services - Public passenger transport - Definition of the quality of service, goals and measurements") "the service provider should promote the monitoring of customer fulfilment as to whether the organization met its requirements" and that customer satisfaction surveys should be carried out annually. Customer satisfaction surveys should assess the degree of reliability of the service, accessibility, available information and time (duration and time compliance) (Law no 52/2015 in Diário da República).

3. Project contextualization

This chapter includes the presentation of OPT to contextualize the reader regarding the proposed challenge. It will be depicted and reflected upon further. Lastly, the structure of the project and the adopted methodology are presented.

3.1. Company presentation

OPT, Optimização e Planeamento de Transportes, S.A., (Optimization and Transportation Planning), is a technological company based in Porto. It emerged in 1992 as a spinoff of a project developed by the Faculty of Sciences at the University of Lisbon (FCUL) and the Faculty of Engineering at the University of Porto (FEUP). OPT still maintains a close relationship with FEUP. Over the years, OPT has also developed a partnership with the Institute of Science and Innovation in Mechanical Engineering and Industrial Engineering (INEGI) which transfers the academic knowledge of technological products and processes to provide innovative solutions to the market. This partnership is based on shared projects and resource recruitment, namely in the area of computer engineering. OPT currently counts on the collaboration of fifteen people and the revenue rounded €800k in 2018.

OPT develops solutions within three distinct business areas, presented in Fig. 12. The products created within the scope of operations management are mainly requested by transport operators. Passenger information solutions are provided to transport operators and institutional entities such as municipalities. Lastly, consultancy studies are sought by institutional entities and private companies. OPT clients are large passenger transport operators including Carris, STCP, Metro do Porto, Horários do Funchal, Transdev, Barraqueiro Group, CP - Comboios de Portugal and Serviços Municipalizados de Transportes Urbanos de Coimbra (SMTUC).

Figure 12 - Business areas within OPT

Over the years, OPT has established itself in the market as a pioneer in the conception of optimized transport planning and management solutions and in the automatic generation of information to the public. The company continued to grow and expanded its offer to consultancy work for operational transport planning. Due to increasing market demand for more sustainable mobility solutions, OPT started to develop consultancy work in the areas of accessibility and mobility based on the current paradigm shift within the sector. Having been a pioneer in this area, OPT has always maintained a position of innovation and customer orientation consistent with the various technological solutions launched in the market to date.

Operations Management

- **GIST**

GIST (Integrated Management of Transport Systems) is a software package with several modules for the operational planning of public transport, which enhances customers' ability to manage their fleet by relating the various variables included in the network. It also allows the generation of vehicle and driver schedules, including their daily scaling, in an optimized way. By using complex optimization algorithms, the software presents the operator with a series of alternatives through graphical interfaces designed to facilitate usability. These consider traditional procedures and habits of planning to consequently ease the decision-making process. GIST manages the information generated by the transport network in an optimized way by combining the network and travel data. The complete version of GIST consists of a set of modules, each with a specific function that assists the user during the planning process:

- **Network**: this module is responsible for characterizing the network by defining the nodes, segments, seasons and types of vehicles
- **Mega lines**: this module defines the offer regarding the routes made available by the company and respective schedules and frequencies
- **Trips and vehicles**: this module creates shifts by assigning vehicles to trips according to the established offer and considering the schedules and frequencies
- **Services**: this module assigns drivers to shifts aiming for an optimal solution that can be evaluated considering its efficiency
- **Rostering**: this module allows management of the availability of crew personnel, construction of theoretical scales with long validity periods and assigning drivers to pre-established dates

The innovative nature of GIST is essentially due to its high level of graphic interactivity with the user, the ease of parameterization, the automation of scheduling processes and the integrated management of data that, at any moment, provides updated and consistent information internally and to the public. It further allows, in a uniform and automatic way, the provision of information on routes and schedules.

- **GeoRef-Map**

Subsequently, the GeoRef-Map product was launched, and it is responsible for georeferencing of the transport network and, thus, provides operators with updated information on the exact location of their routes and stops.

- **MOBUS**

OPT's services include continuous monitoring of its customers, especially through maintenance, updating and training. This results in an environment of value co-creation and partnerships where product functionalities, supported by technological advances, increasingly meet customers' needs and requirements. One of the latest products regarding operations is MOBUS (Fig. 13) which is an integrated platform for Demand Responsive Transport (DRT). MOBUS is a mobility system that focuses on territory inclusion by increasing the coverage of public transport services as an alternative to individual transport in low-offer areas or off-peak hours. This solution includes the necessary components to manage and operate the platform such as the operator system (define the network, stops and gathers relevant statistical data), user app (request the service), call center (for passengers without Smartphone), driver app (establish pick up points and view customers' profiles) and route planning and cost optimization tools.

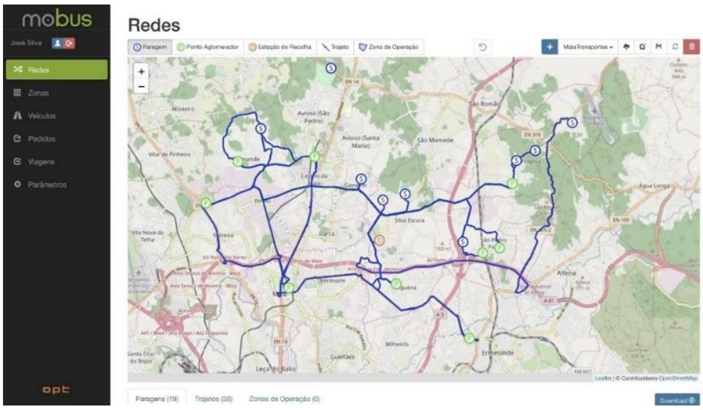


Figure 13 - Different components of MOBUS (operator system, user app and driver app)

Passenger information

The company's credibility has been increasing in the sector. It was internationally distinguished in the area of passenger information (2007) after investing heavily in a partnership with FWT (London based company that supplies high quality passenger information). From this partnership, products such as InfoPub and SpiderMaps emerged to focus on optimizing the creation and dissemination of information to the passenger. The quality of the public transport service also encompasses the means used by the operator to disclose information about the service offering.

- **InfoPub**

InfoPub allows operators to generate automatic information for the public by being integrated with other services that provide the necessary data. It focuses on integration with other systems, editing of public information data, and the rapid and automatic production of advanced graphic layouts whose content dynamically adjusts to the presented data and can be adapted to different references (network, line, stop). These features are distributed by a data management module and by several document generators – BusMap and BusSched (Fig. 14) – to produce stop information regarding routes and schedules while indicating other places of reference known to the public, expected travel times and interfaces. By managing data from other systems, InfoPub extracts all the necessary information from various sources and proves to be an useful aggregator of intermodal information. It can be exported to the GTFSS (Google Transit Feed Specification) format and it is compatible with Google Maps. The standardization of information is effective in reducing errors produced by the manual introduction of the data which allows the configuration of the information according to possible changes of format.

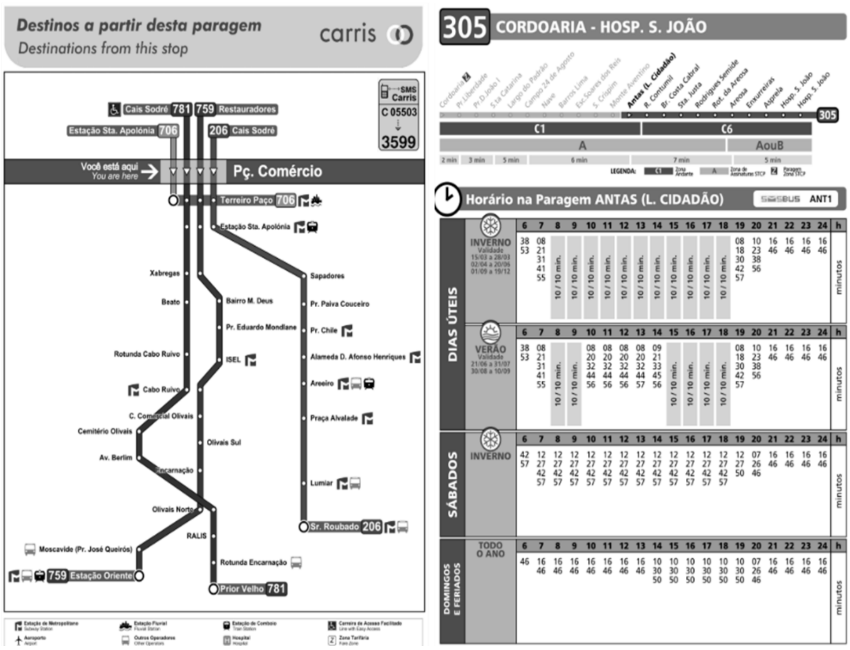


Figure 14 - InfoPub (information generated by BusSched and BusMap)

- **SpiderMap**

In turn, SpiderMaps (Fig. 15) represents the transport network as a whole, rather than privileging geographical correction. Thus, users are aware of the different explicit alternatives on the map without compromising the spatial distribution of the reference points. These maps are ideal for multimodal networks to showcase the existing interfaces which, like InfoPub, are produced automatically. This tool also includes an easily understandable index that indicates the destinations from a reference zone, as well as reachable routes and stops. In the SpiderMap, the Hub is indicated which represents the target area where the observer is located, in order to facilitate the real perception of the space regarding all transport alternatives and exact location of respective stops and other points of interest.

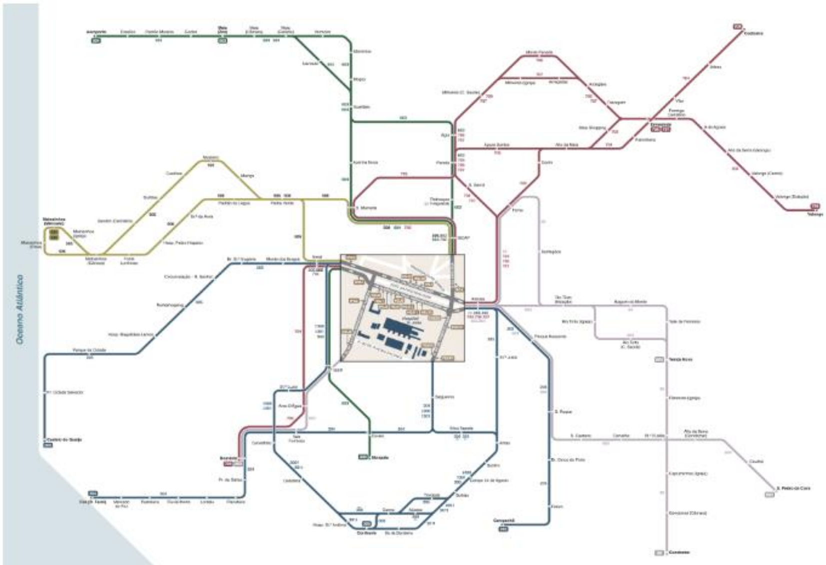


Figure 15 – SpiderMap

- **InfoBoard**

InfoBoard is a system that presents real time information in large screens (Fig. 16) in stations and hospitals, etc. This technology is particularly useful in areas of high multimodality and affluence. The dynamic character of InfoBoard allows the presentation of schedules, stops, destinations, waiting times and points of interest. It gathers all the information about timetables in real time, expected time of waiting for the next vehicle, vehicles in approach for each line, representation of stops and routes with arrival alerts, map of the local offerings and main destinations, services and alternative routes. Screens present information on the vehicles approaching in radial representation with the reference location representing the center while the proximity to the midpoint reflects time distance of the vehicles to the specific place. The map shows the schematics of available stops considering the place of reference and its routes, while the arrival of a vehicle causes a visual alert on the arrival stop. The destination table represents the network taking into account the available operators and their destinations.

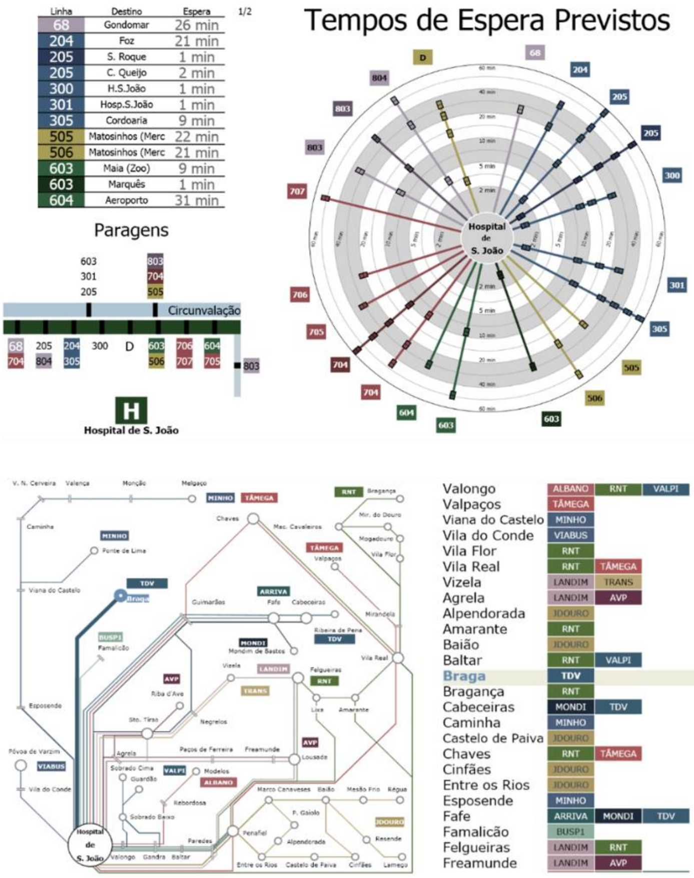


Figure 16 - InfoBoard displays (time of arrival and next departures)

- **SMSBUS**

Georeferencing technology has evolved alongside the dissemination of wireless networks across cities, therefore, OPT has seized the opportunity to develop one of the first real-time systems through a cellphone. SMSBUS allows users to access information in real time referring to a specific stop, via SMS. This service accesses the information regarding the positioning of vehicles and, by sending a text message containing the stop code, the user is informed about the time of arrival of the next buses.

- **MOVE-ME**

More recently, and due to the evolution of mobile technologies, OPT developed MOVE-ME (Fig. 17), an innovative mobile application that allows access to a diverse and complete set of information about the public transport available in the city. MOVE-ME brings together updated data from different operators through the actual positioning of the vehicles. Users benefit from information on the next arrivals based on their specific location (or through another location they indicate), associated waiting times, as well as information about the location of stops and main points of interest. The application allows users to plan trips by describing waypoints defined by the user and which, when interconnected, create routes of choice. To search for the next departures, the system allows the selection of stops by touching an interactive map, by writing the code or part of the name of the stop, or by choosing the operator and the respective routes. The app stores recently used stops to suggest alternatives according to the personal usage of the service. Stops can be consulted by indicating the respective location on the map or by defining it textually. It also identifies which stops are closest to the user's position and which are the next trips and destinations. It is possible to consult the nearest points of interest by selecting a radius of search to obtain the available routes. The system informs the time of passage at each stop, as well as the interfaces and footpaths between them. Routes are available in the history to be reused later. Despite the numerous features of MOVE-ME, some have opportunities for improvement in terms of user experience and integration.

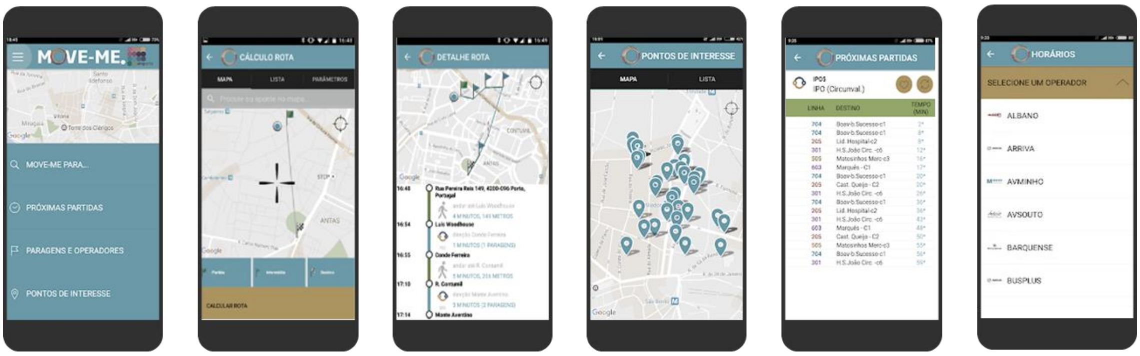


Figure 17 - Several features of MOVE-ME (main menu, route calculation, route details, points of interest, next departures, operators available)

- **ANDA**

In 2018, OPT was involved in the development of the ANDA mobile application (Fig. 18) that replaces the physical Andante card, allowing for payment of the trip through Smartphone and post-paid system. Operating in the MAP and for Android devices, ANDA enables traveling through the Andante network without necessarily having to know its zoning system, and in addition, by using intelligent algorithms it optimizes the tariff and calculates the most advantageous price taking into account the destination. When installing the application, users insert their personal account and payment data. To use ANDA, the user must turn on the application and validate the trip with the Smartphone, just like the validation with the Andante card. At the end of each trip, the Smartphone stops communicating with the beacons in the vehicle and terminates the connection.

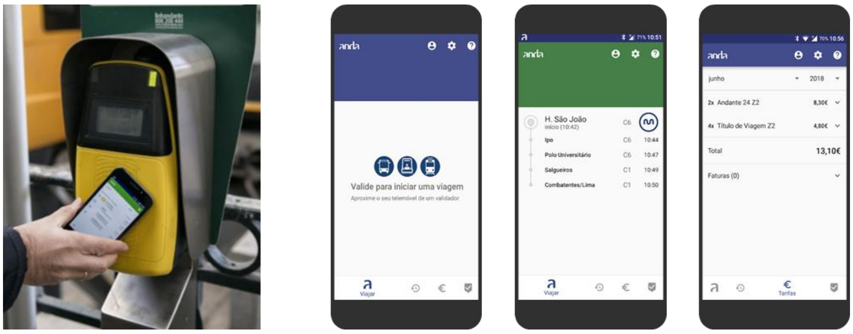


Figure 18 - Validation with ANDA and several ANDA functionalities (start of trip, stops, tariffs)

Consultancy in Urban Mobility

Current trends manifest the need to qualify public transportation as a combination of modes capable of serving society's needs in urban areas. OPT has invested in a mobility and transport consultancy department whose projects reflect the growing need to design flexible mobility services in areas of low population density, realignment and rehabilitation of infrastructures considering the energy-environmental balance, the promotion of networks of pedestrian paths and cycle paths, the creation of mobility plans (Fig. 19) for municipalities and improvement of the quality of information and communication to the public in real time. OPT participates in analysis studies in planning processes to provide decision support to municipalities in this area.

Figure 19 - Scheme of the conceptual model of mobility plans

Regarding collective transport, OPT develops projects for the redesign and restructuring of the networks (Fig. 20) by means of special methodology of survey and factorial modelling, namely at the level of flexible transportation systems (DRT), while further analysing the performance of the existing offerings.

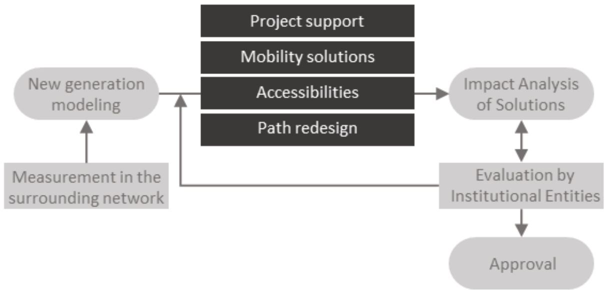


Figure 20 - Framework for urban design of accessibilities and traffic studies

Customer satisfaction monitoring practices represent a fundamental tool for the evolution of public transport systems and urban mobility in general and should be carried out periodically by the entities responsible for this purpose. The quality of the service provided depends on a set of requirements/needs that must be noticed and, if possible, the services themselves must be adapted to the specifications required within the framework of the economically feasible.

OPT also develops traffic studies for commercial, industrial or residential scenarios to assess the impact of such projects by modelling through induced generation and microsimulation, analyses the licensing processes, with the design of urban measures and solutions to mitigate the same estimated impacts. These are based on urban designing of accesses, roadways and parking lots. The redesign of urban space in new configurations considers the introduction of soft modes due to their increasing importance and the implementation of vectors of traffic calming.

3.2. Challenge

The use of the Smartphone has been increasing exponentially in recent years and people are increasingly turning to these devices to manage their day-to-day lives. Like many other companies, OPT understands that there is an enormous potential for the Smartphone in urban mobility. In this way, the challenge launched for the purpose of this project lies in the development of a new concept of interaction between the providers of mobility services and the passenger through the Smartphone. This concept is based on the adoption of the Smartphone as a method to solve problems related to information updates and integration regarding the offer of services in a more efficient and cost-effective way. On the other hand, it is possible to improve user experience and promote the interaction between the operator and the customer through a more sustainable solution since it reduces the need to use natural resources (paper). Although there are already mobile applications that display information about the public transport offerings and that include some degree of interactivity with the user, from the point of view of the OPT, this interaction can be taken to the next level.

OPT proposes the improvement in the degree of integration between key features and identifies the opportunity to take advantage of the data generated from the interaction between operator and passenger since it allows the generation of relevant information about customer satisfaction towards the service.

As shown in Fig. 24, the Smartphone is a bilateral tool since it displays information on the available services while allowing the user to systematically evaluate the service.

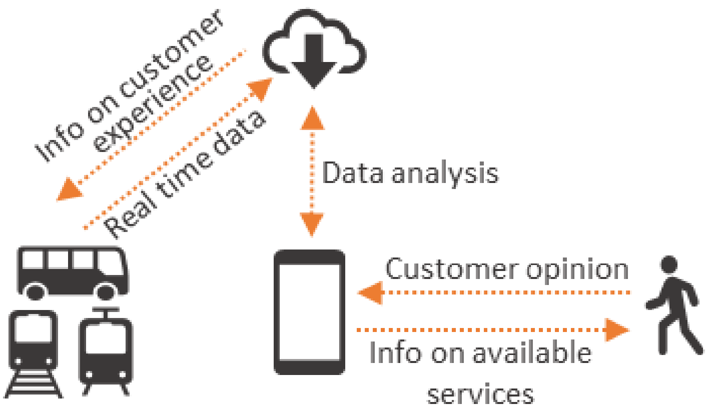


Figure 21 - Communication flow between service provider and user through the Smartphone

Taking into account the theoretical principles set out in Chapter 2 and based on the premise that mobility is increasingly important to follow the trend of more personalized service provision it is imperative for operators to disclose relevant data so that mediators, such as OPT, can manage the information in an integrated way. It is already possible to know the actual positioning of vehicles, the question is to make this information accessible and integrated so that it can be made available to the user, who is the final decision maker.

The project aims to reflect on a new concept of platform where the service provider and the user can communicate in a clear and relevant way based on the principle of value creation. Although it seems a vague problem, this project aims to reach a new level of usability, interactivity and added value.

Thus, considering the company's challenge, it is intended to improve access to information with the use of the Smartphone regardless of age, gender or literacy, so that people can take control over their mobility just as they do when using a private vehicle. The personalization of this service aims at facilitating decision making and bringing stakeholders together to promote interaction and consequently improve customer satisfaction.

The final goal of this project is to contribute to a more sustainable future by promoting the use of public transportation through the enhancement of its services. This can be achieved by enlightening citizens on the service offered in a clear, seamless and personalized way. However, another difficulty encountered in similar context projects is the difficulty in effectively integrating multimodality and different features. As previously shown, it is clearly impossible to serve the public transport user at a door-to-door level if only one mode is considered, however, through the integration of services and diversity of alternatives it is possible to create a network of routes that may compete with the advantages of the personal vehicle. The notion of transhipments implicit here and it is increasingly common in urban areas that the population uses various transports to reach the destination. It may be argued that waiting times are long but the access to information about these waiting times allows the user to choose from a variety of alternatives that the application returns and thus to have a better travel experience. The interactivity of the tool also requires input from the user in order to personalize the service. In this sense, the user can choose between, for example, walking shorter foot paths, minimum waiting time between transhipments, fewer transhipments, lower cost, etc. These features are similar to Google Maps route calculation, where the user can apply specific conditions.

3.3. Project methodology

This project has the MAP as a starting point for developing a concept that could be scaled to other cities, so it begins by characterizing the MAP as region regarding its population, territory, mobility services available and mobility patterns. Then the current situation considering passenger information available at the MAP was reflected upon to conclude this characterization and to identify opportunities for improvement in this area. This means of communication and available information at bus stops, metro stations and online platforms were identified and analysed to understand the offer situation regarding passenger information in the MAP.

Then, a survey was carried out to understand the perspective of the public transport passenger population in the MAP to assess the current level of satisfaction with the information disseminated by the operators, and the most requested or most important mobile features for users. This section includes the objective of the survey, the sample selection method, the process of data collection, data analysis and results interpretation.

After evaluating the results of the survey and establishing the current situation, the study proceeded to analyse the requirements for the design of a new concept of mobile application. At this point, knowledge acquired from the research carried out in the field of passenger information was used to compare realities and enrich the project by reflecting on success cases of passenger information concepts implemented in other cities.

When projecting the concept of mobile applications, the features to be included as well as the general characteristics were carefully considered. The implementation of these features was developed based on usability concepts which ease the app's utilization and UML tools. Given this, some technological aspects required for the development, implementation and follow-up of the system were presented so that the application could be, theoretically, effectively applied. To exemplify the degree of interactivity and access, an application mock-up was developed and presented through UML tools.

OPT's challenge raises the prospect of creating a potential business strategy for the project. It is important to analyse the relevant aspects of its implementation and design innovation and business strategies due to the different stakeholders involved in such a project. In this section, Blue Ocean theory is reflected upon considering this specific project followed by the presentation of a Lean Canvas (which is a canvas template from Lean Startup methodology) and a SWOT analysis to identify key aspects of the product. These models are very useful to easily and graphically distinguish the characteristics of the product and its general implications for the company.

4. Project development and results

The present chapter contains the report of the developed project itself. It starts with the analysis of the current situation regarding passenger information. Then a new conceptual model is proposed to improve the interaction between service providers and users through a mobile app. Lastly, strategies regarding innovation and business are presented for the mobile application.

4.1. Analysis of the current situation

The following analysis presents the available channels, the information provided in the MAP and the survey carried out in several routes provided by different transport operators. The argumentation culminates in the comparison between supply and demand to define the way forward in a feasible and customer-oriented way.

4.1.1. Urban Mobility in the MAP

Since OPT focuses its activity on the MAP, this section presents a characterization of the MAP as a region considering its population, territory and public transport offering. It also includes the identification of the available communication channels and the information displayed.

4.1.1.1. Characterization of the MAP

The Metropolitan Area of Porto (MAP) is located in the Northern Region of Portugal, more precisely on the North Coast of Portugal and covers an area of approximately 2,040 km² with approximately 1.719.371 inhabitants (PORDATA 2018a).

It is composed of 17 municipalities presented in Fig. 22 (Arouca, Espinho, Gondomar, Maia, Matosinhos, Oliveira de Azeméis, Paredes, Porto, Póvoa de Varzim, Santa Maria da Feira, Santo Tirso, São João da Madeira, Trofa, Vale de Cambra, Valongo, Vila do Conde and Vila Nova de Gaia). The Municipality of Vila Nova de Gaia has the largest number of residents, accounting for 17,2% of the total population, followed by Porto (13,5%), Matosinhos, Gondomar and Maia. respectively, 10,0%, 9,5% and 7,7% of residents. On the other hand, Arouca and São João da Madeira are the municipalities that present the lowest proportion with 1,3% and 1,2%, respectively. In the population density, there is a great heterogeneity, since the municipality of Porto presents 5.739 pop/km² while Arouca presents 68 pop/km² (mpt 2016).

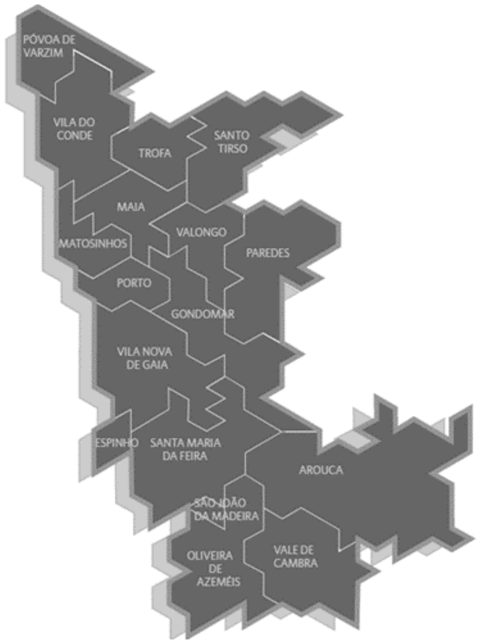


Figure 22 - Map of the municipalities constituting the MAP – retrieved from AMPorto (2019)

In 2011, around 66% of residents commute within the municipality of residence and the remaining 34% work or study in another municipality. There has been an increase in travel between municipalities, with emphasis on Vila Nova de Gaia-Porto, Gondomar-Porto, Matosinhos-Porto and Maia-Porto. Except for Porto, which is the main destination of the commuter movements from outside the MAP, the municipalities of Maia, Santo Tirso, Paredes, Santa Maria da Feira and Trofa also stand out. The MAP shows a high dependence on individual transport, representing about 63% of the residents' commuting options. The pedestrian mode represents about 16%, the bus about 12% and the metro approximately 3,5% (mpt 2016).

Collective road transport is particularly relevant in the municipalities of Gondomar (20%), Porto (17%) and Vila Nova de Gaia (14%), that together with the municipalities of Valongo (13%), Matosinhos %) and Maia (10%), represent the area of influence of the STCP transport network. Regarding the movements within the same municipality, Porto (19%), Gondomar and Vila Nova de Gaia (14%) are the municipalities with the most movements. Collective road transport between municipalities is of particular relevance in the municipalities of Gondomar (24,7%), Valongo (16,2%) and Vila Nova de Gaia (15%), and the overall value for MAP is 13%.

The use of the metro (Metro do Porto) is directly related to the configuration of its network, since the municipalities in which the operation is carried out are those where there is a greater use of this mode of transportation. Thus, the municipalities of Maia (4.2%), Matosinhos (7%), Porto (7.5%), Vila do Conde (5.1%) and Vila Nova de Gaia (4.2%) present higher rates of metro utilization, being even higher than the MAP average (3.5%). The municipalities of Gondomar (3.2%) and Póvoa de Varzim (3.3%) have a utilization rate below the global average (mpt 2016).

Regarding collective road transport, the MAP benefits from the service of 29 passenger transport operators. STCP occupies a leading position in the MAP since the public transport company operates a network that serves the municipalities of Porto, Matosinhos, Vila Nova de Gaia, Maia, Valongo and Gondomar. At the MAP, other companies such as Valpi and Transdev are particularly active in road transport in the eastern and southern areas, respectively. Metro do Porto directly supplies the municipalities of Porto, Vila Nova de Gaia, Matosinhos, Maia, Gondomar, Vila do Conde and Póvoa de Varzim. The metro network has 81 stations. This system is used by 56.923 million passengers/year and most of its clients live in the municipalities of Porto, Vila Nova de Gaia and Matosinhos, followed by the remaining municipalities covered by the network: Maia, Gondomar, Vila of the Conde and Póvoa de Varzim (mpt 2016). Although Metro do Porto is considered a rail transport, its contribution to urban transport in the MAP is of particular relevance given that it is the backbone of the transport network. CP Comboios de Portugal also carries out transportation between municipalities in the MAP but ends up having a more inter-regional role.

4.1.1.2. Passenger information available in the MAP

The following channels were examined: bus stop, metro station, operator website, operator app and mobile application.

The existence of static information brings some benefits to the user such as access to information *in situ* that allows for checking the routes, timetables and frequencies. The available maps also indicate intermodal options as they identify the interfaces with other available transports. Bus shelters include city maps with different routes, a BusSched and a BusMap for each available route and respective interfaces, and fares. Usually, bus stops without shelters are identified with the post containing information about the bus routes and their destination.

Metro stations contain a lot of information: fares according to the destination to facilitate the purchase of tickets and compliance with the zoning system, regulation on how to carry bicycles on board the vehicle, a color conversion system for the color blind, the network map, timetables and frequencies of the different routes of a specific station, etc. In terms of bus services, despite being quite common in the city center and in the border municipalities, bus stops with shelter are rare in less urbanized areas and peripheral municipalities of the MAP.

Figures 23 and 24 present the physical information available at standard bus stops and metro stations.

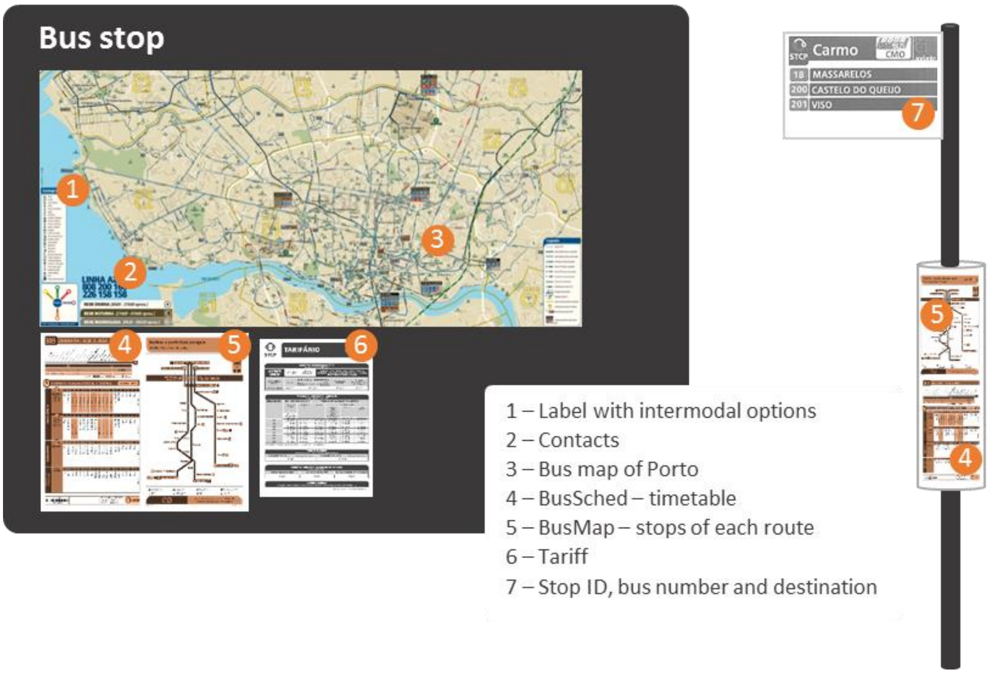


Figure 23 - Information available at bus stops within the MAP

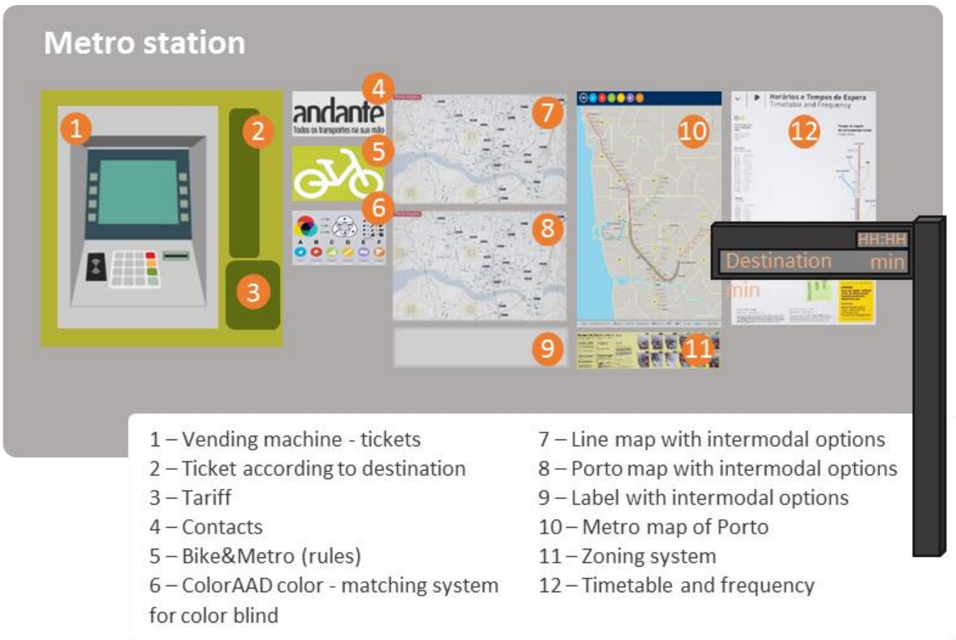


Figure 24 - Information available at metro stations within the MAP

The websites considered for this study correspond to each transport operator. The following features are included in following websites: complaints/suggestions; available services; tariff and monthly packages; timetables; routes and stops; utilization rules; contacts; media. Table 5 presents some features which are not included in every website.

Table 5- Features of operators' websites

Features	Metro do Porto	STCP	Transdev	Valpi
Customer satisfaction surveys	-	-	✓	-
Network map	✓	✓	✓	-
Service alterations	-	✓	✓	-
Plan trip	✓	✓	✓	-
Parking	✓	-	-	-
News	✓	✓	✓	-
Login	-	✓	-	-
Language	PT/ ENG	PT/ ENG	PT	PT/ ENG

Transdev allows customers to respond to satisfaction surveys through the website. Network maps are helpful to understand the localization of stops, net distribution and routes. Both Transdev and STCP inform on service alterations. Except for Valpi, the remaining websites enable trip planning which is a friendly feature for passengers that do not use Smartphones and for non-regular passengers. To improve information on available interfaces, Metro do Porto displays parking options according to each station, so the user knows if it is possible to park in the immediate areas. This promotes the use of public transport because people can go from a peripheral to central hub by metro. News about the company can be interesting to the user and provide extra information on the service or future updates. The login feature recognizes the user and saves relevant data according to specific searches. It could also provide access to a user account where it is possible to manage the profile, tariff or package in use, and relevant and directed information due the specific use of the service.

Regarding mobile applications, table 6 shows that some features are already well implemented across the various apps however, some information is not fully reliable because the infrastructure required to monitor the vehicles' location is not generally deployed across the network and its performance is not at top level yet. Also, the public transport sector is shifting from a mindset of competition to an integrated perspective where different services complement each other, therefore, open data platforms are being developed to present more accurate and relevant information to the users. Another important aspect of digital information is that it must be displayed in languages other than Portuguese due to tourism. Apart from static information such as timetables and available interfaces (generally), the underlined features represent real time information and some degree of multimodality which will likely become a key concept of mobile applications.

Table 6 - Features of the mobile applications

Feature/ App	iMetro do Porto	Porto.Bus	myTransdev	Easy Bus	Move-me.AMP	Moovit
Trip planning	✓	-	✓	-	✓	✓
Next arrivals	✓	✓	✓	✓	✓	✓
Timetables	✓	-	✓	-	✓	-
Network map	✓	-	✓	-	-	-
Routes and stops	✓	✓	✓	✓	-	✓
Map with routes/stops	-	✓	✓	✓	✓	✓
Service alteration alerts	-	-	-	-	-	✓
Points of interest	-	-	-	-	✓	-
Contacts	✓	-	✓	-	✓	✓
Login	-	-	-	-	-	✓
Favourites	-	✓	✓	✓	✓	✓
Location-based info	-	✓	✓	✓	✓	✓
Real time info	-	✓	-	✓	✓	✓
Integration with Google Maps	-	✓	✓	✓	✓	-
Shared mobility integration	-	-	-	-	-	✓
Multimodality	-	✓	-	-	✓	✓
Notifications/ alarms	✓	-	-	✓	-	✓
Advertisement	-	-	-	✓	-	-
Tariff	✓	-	-	-	✓	-
Interfaces	✓	✓	-	-	✓	✓
News	✓	-	-	-	-	-
Languages	PT	-	PT/ENG	PT	PT	PT

4.1.2. Survey about passenger information at the MAP

In order to deepen the knowledge about the passenger information situation in the MAP, a survey was conducted, with special emphasis on the data analysis performed.

4.1.2.1. Objective

The objective of the survey conducted was to clarify passengers' position towards the transport information available in the MAP and the way it shall evolve. The aim was to characterize the respondents in terms of their general characteristics (GC), use of public transport (PT), access to passenger information (PI) and app usage potential (AP).

4.1.2.2. Sample selection

Considering the purpose of the survey, the ideal would be to use the mobile population of MAP to calculate the sample size, however, the distribution according to gender and age range are not known and it was decided to use the resident population as reference (1.719.371 inhabitants) (PORDATA 2018a). A population of 1.719.371 inhabitants is considered large so, the following equation was used to determine the sample size (Israel 1992):

$$n = \frac{Z^2 * p * (1-p)}{e^2}$$

Z: Z-score
p: population proportion
e: margin of error

Determining sample size (n)

In order to determine the sample size based on the confidence level and the tolerated margin of error suitable for the study, several combinations presented in table 7 were discussed, since the estimated proportion was unknown, to ensure the oversizing of the sample p = 0,5 was used (Israel 1992).

Table 7 - Determination of sample sizes considering different confidence levels and margins of error

		Tolerated margin of error (e)			
Confidence level	**Z-score**	**4%**	**5%**	**8%**	**10%**
90%	1,645	423	271	106	68
95%	1,96	600	384	150	96
99%	2,575	1036	663	259	166

For the purpose of this study a 95% confidence level and a 5% margin of error were adopted which resulted in a minimum of 384 surveys that were subsequently rounded up to 400.

According to the technological nature of the subject, some adjustments were made regarding the distribution of the sample size by age group. Since the population over 65 represents 20% of the total MAP population (table 8), 30% of these surveys (23 surveys) were distributed by the remaining age groups in order to mitigate the influence of those who are usually considered as laggards regarding technology in the context of public transport. By distributing 30% of the surveys that would be otherwise completed by the elderly, it was still possible to ensure a representativity of around 14% in the total number of surveys carried out. In addition, no under-14s were surveyed as parental consent is required and, given that the future generations will increasingly use technology, the 55 surveys that would be attributed to this population (table 9) were distributed by the 15-19 and 20-24 age groups. This distribution was made in order to maintain the proportions in terms of gender and age, since these are the individuals with more similarities regarding the use of technology and will be future passengers of public transportation. Table 10 indicates the actual number of surveys conducted according to gender and age group.

Table 8 - Population of the MAP per age group and gender (PORDATA 2018b; PORDATA 2018c)

	Age groups						
Gender	**≤14**	**15-19**	**20-24**	**25-44**	**45-64**	**≥65**	**Total**
Female	114.563	46.208	44.648	234.519	274.089	195.250	909.277
Male	118.828	48.046	45.856	217.104	237.739	142.521	810.094
Total	233.391	94.254	90.504	451.623	511.828	337.771	1.719.371

Table 9 - Number of surveys per age group and gender equivalent to the distribution of the population

	Age groups						
Gender	**≤14**	**15-19**	**20-24**	**25-44**	**45-64**	**≥65**	**Total**
Female	27	11	10	55	64	45	212
Male	28	11	11	50	55	33	188
Total	55	22	21	105	119	78	400

Table 10 - Number of surveys per studied age groups, gender after the distribution of 78 surveys

	Age groups					
Gender	**15-19**	**20-24**	**25-44**	**45-64**	**≥65**	**Total**
Female	26	25	59	69	32	211
Male	27	26	54	59	23	189
Total	53	51	113	128	55	400

The survey includes four of the main passenger transport operators in the MAP, covering the private sector (Valpi and Transdev) and the public sector (Metro do Porto and STCP). The routes in which the survey was conducted cross the MAP in the north-south and east-west directions (Fig. 25) and cover a wide variety of passengers.

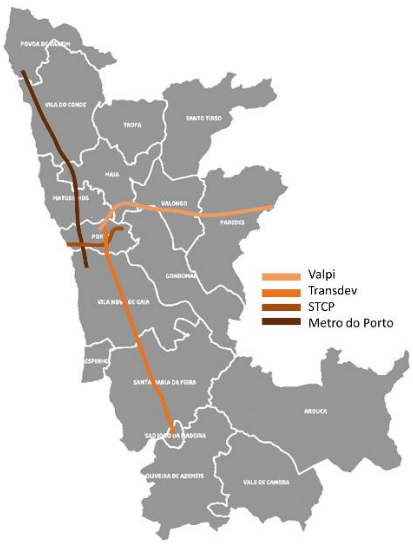


Figure 25 - Map with the routes by operator in which the survey was carried out

4.1.2.3. Data collection

Surveys were conducted in person to ensure the correct distribution of the sample in relation to gender and age group and to collect feedback from passengers while completing the survey. These were carried out in the context of bus stops/metro stations (while the passenger was waiting) and during the transport along the routes chosen previously. The Google Forms tool was used to develop the survey so that it could be carried out with the Smartphone and the responses recorded automatically in an excel file on Google Drive. Knowing that both waiting and travel times may be short, the survey had to be clear and short enough to ensure its understanding and the collection of clear results. Most questions are multiple choice (maximum 5 choice options) or yes/no. The last question is an open one and creates a space to capture new ideas and specific opinions to the study in relation to new application features. It is possible to consult the questionnaire in the appendix.

4.1.2.4. Data analysis

Table 11 presents the variables derived from the questionnaire and their respective characteristics. A new variable, **SUM_UT**, is added to the analysis to represent the sum of the scores of every feature, per respondent.

Table 11 - Variables description

Question	Variable name	Variable description	Variable group	Scale
2	**GEN**	Gender	GC	QL nominal
3	**AGE**	Age	GC	QL ordinal
4	**OCCUP**	Occupation	GC	QL nominal
5	**SPuse**	Use of Smartphone	GC	QL nominal
6	**REG**	Regularity of PT use	PT	QL ordinal
7	**MOT**	Trip motive	PT	QL nominal
8	**WAIT**	While waiting	PT	QL nominal
9	**CHAN**	Communication channels	PI	QL nominal
10	**PTApp**	Use of PT apps	PI	QL nominal
11	**SAT**	Satisfaction towards info	PI	QL ordinal
12	**FUT**	Intention to use the app	AP	QL nominal
13.1	**UTop**	Feature: express opinion	AP	QT
13.2	**UTsched**	Feature: schedules and ETA	AP	QT
13.3	**UTalt**	Feature: alterations alerts	AP	QT
13.4	**UThist**	Feature: history-based alerts	AP	QT
13.5	**UTpay**	Feature: e-payments	AP	QT
13.6	**UTplan**	Feature: trip planning	AP	QT
13.7	**UToccup**	Feature: vehicle occupation	AP	QT
13.8	**UTprox**	Feature: nearby events	AP	QT
-	**SUM_UT**	Sum of utility scores per case	AP	QT
14	**SUG**	Any suggestions?	AP	QL nominal

For the ordinal variables considered given the way the questions were designed, the answers can be seen as variables (as if a Likert scale was used).

1 Characterization of the sample

The data analysis begins with the presentation of the distribution of frequencies for each variable, according to the respective variable group. Regarding the group of variables GC, pie charts representative of gender and age group are not presented since they follow the distribution indicated in table 10. From Fig. 26 it is possible to see the distribution of respondents according to **occupation** (over 81% are employed or students) and Smartphone (**SPuse**) use, which is quite broad (90% of the respondents use SP).

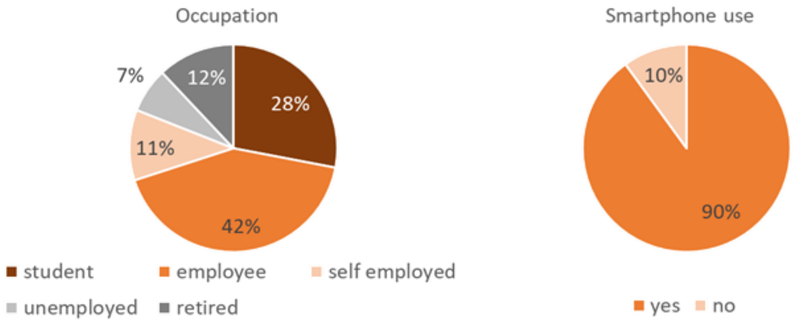


Figure 26 - Graphic representation of GC variables

Figure 27 presents the distribution frequencies for PT variables. According to the results, 74% of the respondents are regular users of public transport, 66% are commuters (trip motive is school/workplace) and 55% use the SP while waiting.

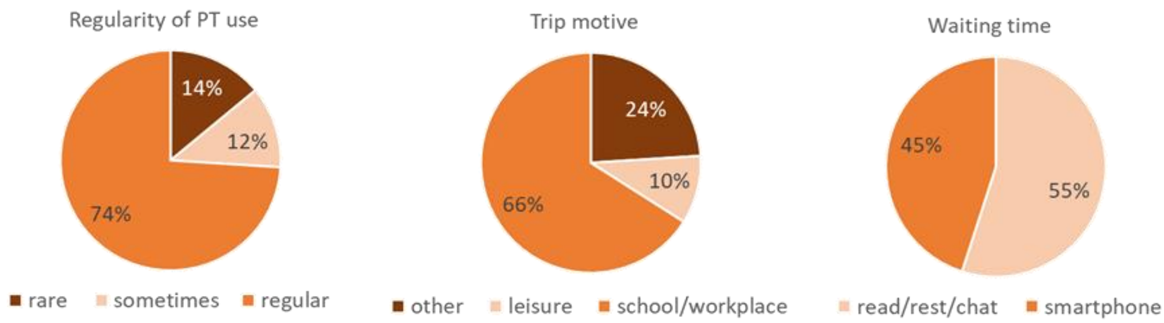


Figure 27 - Graphic representation of PT variables

Considering PI variables, presented in figure 28, 43% of the respondents already use the Smartphone to access passenger information, however, 34% still use the outdated paper boards at bus stops. About 68% do not currently use any app related to public transportation which indicates they might access information through the website on their Smartphones. Despite the high percentage of satisfied passengers (69%), the answers varied according to the communication channel used to access information and this argument is supported by Fig. 29.

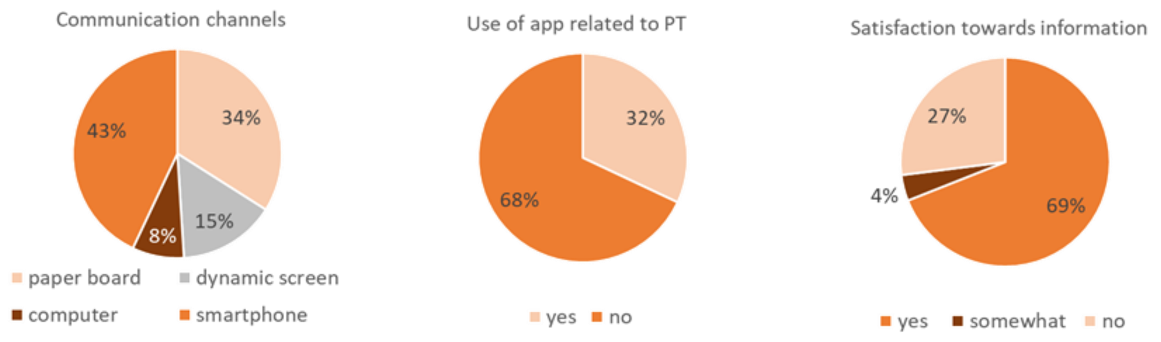


Figure 28 - Graphic representation of PI variables

Metro presents better levels of satisfaction towards passenger information. The quadrant chart presented in figure 29 presents the relative dissatisfaction with each information channel and allows to verify that the paper boards present a higher percentage of dissatisfaction. As previously stated, dynamic displays are associated with the metro and, since it has a less complex network and does not compete with other operators regarding infrastructure (such as buses and other road vehicles), it is easier to meet schedules and have more satisfied passengers. As a physical and static means of providing information, paper boards do not show unforeseen events and do not warn passengers at stops. In this way, we conclude that people are more satisfied with dynamic information, easy to update and in real time.

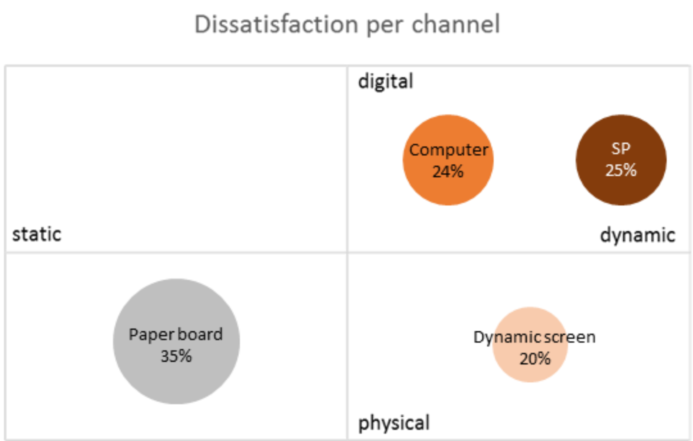


Figure 29 - Dissatisfaction per channel

Figures 30, 31 and 32 present the distribution frequencies for AP variables. Figure 30 indicates that 88% indend to use the mobility app in the future and only 6% have some suggestions regarding what else to include in the app.

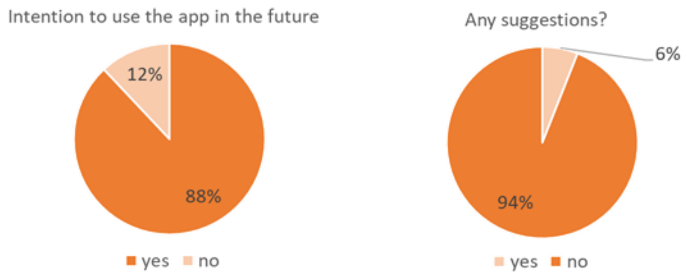


Figure 30 - Graphic representation of AP variables

To assess the utility of each feature proposed, the differences between the sum of frequencies for scores 3 and 4 and the sum of frequencies for scores 0 and 1 can be used (figure 31). Variables **UTsched** (87%) and **UTalt** (86%) present the highest differences. Next, variables **UTop** (61%), **UThist** (74%) and **UTplan** (69%) are in the middle. At last, variables **UTpay** (41%), **UToccup** (34%) and **UTprox** (45%) present the lowest differences.

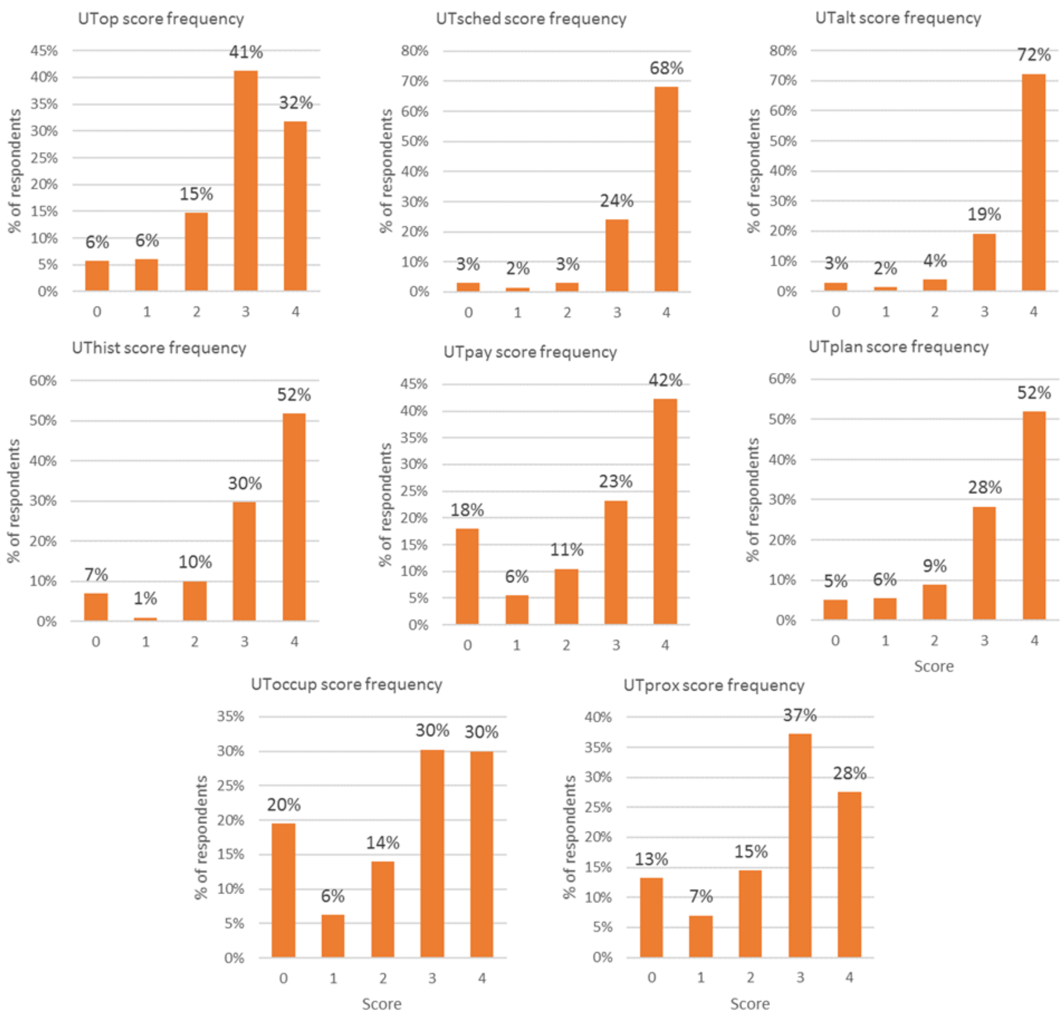


Figure 31 - Utility scores

Figure 32 presents two charts that relate, respectively, the **trip motive** and **regularity of PT use** with the features. As expected, the "school/ workplace" and "regularly" curves are similar because students and workers are the most regular users of public transport. Regarding **UTpay**, it is notoriously overvalued by the commuters in relation to the others. This also happens to **UThist** but regarding regularity of PT use meaning that this feature is more useful for regular users.

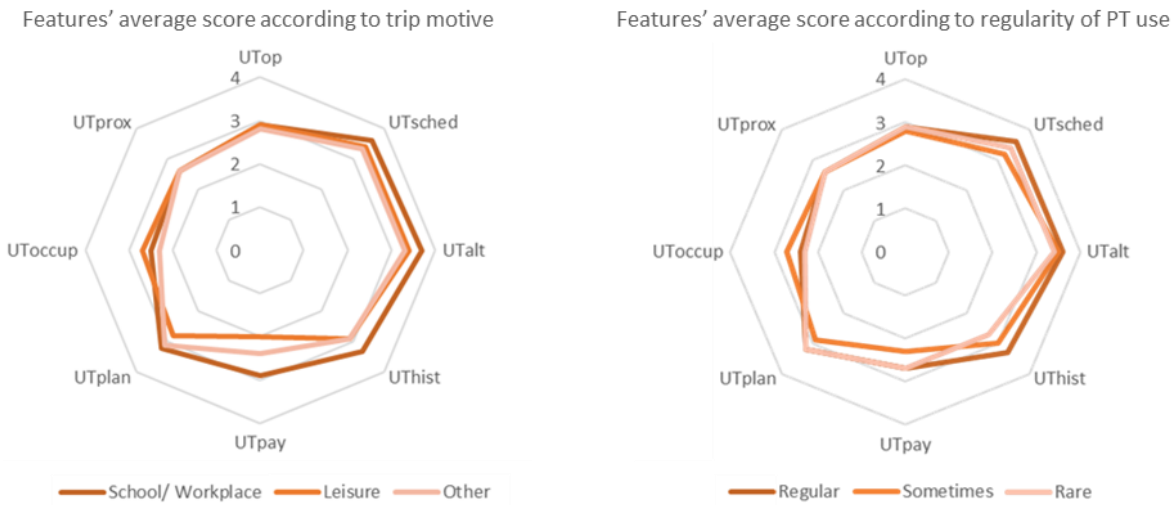


Figure 32 - Features' average score according to trip motive and regularity

Figure 33 shows the distribution frequencies of the sum of scores assigned by each respondent to the features' utility (variable **SUM_UT**).

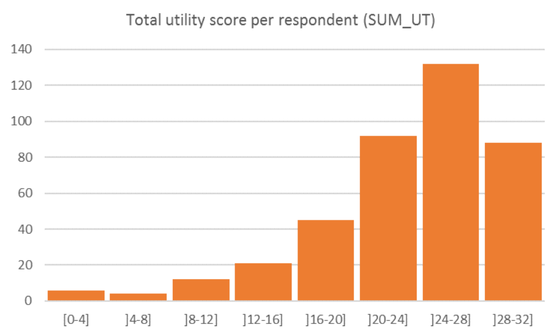


Figure 33 – Graphic representation of the variable SUM_UT

Finally, figure 34 presents graphs showing how the total score (**SUM_UT**) varies depending on the GC, PT and PI variables. The scores assigned by female and male passenger are roughly the same (difference is less than 1 point). Younger users (15-44) assign higher scores compared to the older ones. Smartphone users overvalue features since they perceive the potential of the device as an information tool. Regarding regularity of public transportation use and trip motive, since regular passengers are usually commuters, the results of both variables are closely the same. Passengers who already use the Smartphone to pass the time and use it to access information also provide higher scores. Passengers that have already experienced a PT-related app also defend the utility of the app over the non-users. Different levels of satisfaction towards the available information do not reflect different scores which means that people value the utility of each feature regardless how satisfied or unsatisfied they are.

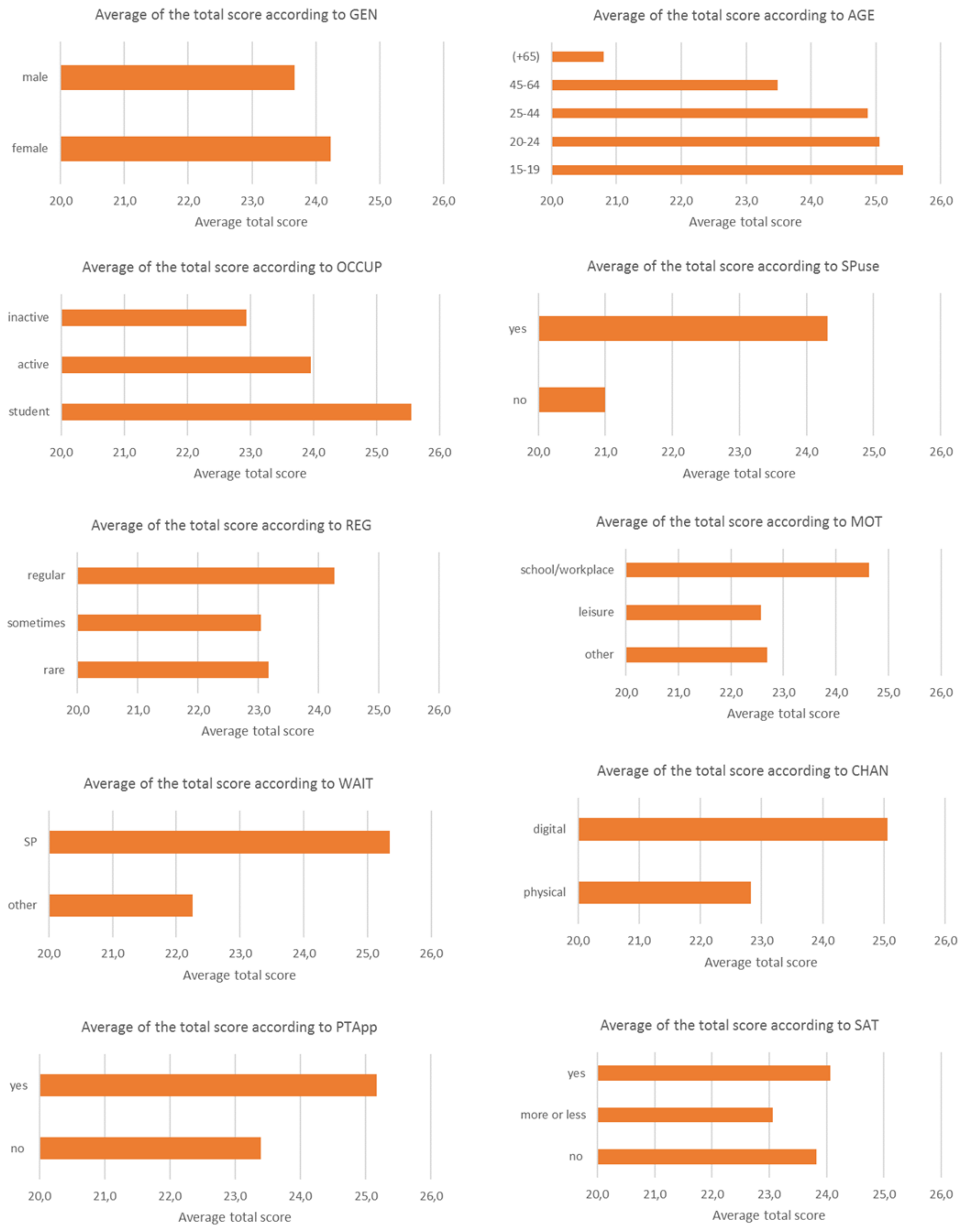


Figure 34 - Average of total score (SUM_UT) according to GC, PT and PI variables

2 Pre-analysis of data

To simplify the analysis, some answers presented as options in the survey were grouped. For instance, regarding **passenger occupation**, employees and self-employed are considered active and the retired and unemployed are inactive. The same was applied to **channels** (paper and dynamic screens are physical channels while mobile apps and computer are digital channels) and to **how passengers occupy waiting times** (rest, read and chat are distinguished from the Smartphone). To apply the statistical treatment techniques to the variable **passenger occupation** (nominal variable) it was necessary to create two dichotomous variables: **OCCUP1** (0 – active/inactive; 1 – student) and **OCCUP2** (0 – student/inactive; 1 - active).

Using SPSS, it was possible to group a set of data into clusters (Cluster Analysis), assess the differences between groups (ANOVA), test the strength of the association between variables (Pearson Correlation), the size for a set of variables (Factor Analysis) and, finally, understand the relationship between one dependent variable and various independent variables (Linear Regression).

GC, PT and PI variables were used to determine clusters of users. Based on the dendrogram shown in Fig. 35, three clusters of passengers have been formed.

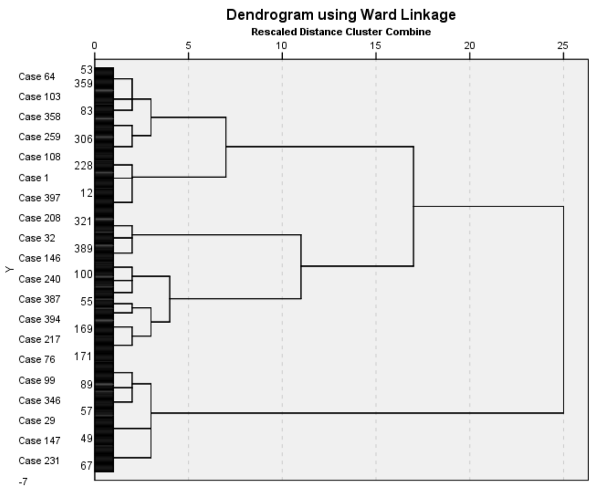


Figure 35 - SPSS output dendrogram for cluster analysis regarding passenger type

The one-way (ANOVA) output illustrated in figure 36 shows that only for gender and info satisfaction the averages are equal between the clusters of passengers considered.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
GEN gender	Between Groups	1,236	2	,618	2,492	,084
	Within Groups	98,462	397	,248		
	Total	99,697	399			
AGE age	Between Groups	295,102	2	147,551	196,511	,000
	Within Groups	298,088	397	,751		
	Total	593,190	399			
OCCUP1 occupation 1	Between Groups	78,757	2	39,379	15744,949	,000
	Within Groups	,993	397	,003		
	Total	79,750	399			
OCCUP2 occupation 2	Between Groups	62,873	2	31,437	338,914	,000
	Within Groups	36,824	397	,093		
	Total	99,698	399			
SPuse use smartphone?	Between Groups	8,101	2	4,050	54,527	,000
	Within Groups	29,489	397	,074		
	Total	37,590	399			
REG PT regularity	Between Groups	56,332	2	28,166	76,043	,000
	Within Groups	147,046	397	,370		
	Total	203,378	399			
MOT trip motive	Between Groups	199,814	2	99,907	451,043	,000
	Within Groups	87,936	397	,222		
	Total	287,750	399			
WAIT waiting time	Between Groups	15,748	2	7,874	37,595	,000
	Within Groups	83,150	397	,209		
	Total	98,897	399			
CHAN info channels	Between Groups	9,102	2	4,551	19,884	,000
	Within Groups	90,858	397	,229		
	Total	99,960	399			
PTApp use PT app?	Between Groups	4,477	2	2,239	10,764	,000
	Within Groups	82,563	397	,208		
	Total	87,040	399			
SAT info satisfaction	Between Groups	,574	2	,287	1,455	,235
	Within Groups	78,246	397	,197		
	Total	78,819	399			

Figure 36 - SPSS output for ANOVA between passenger clusters

Regarding the other variables, figure 37 helps finding which passenger clusters have different averages. For instance, considering the regularity of PT use (**REG**), clusters 1 and 3 have similar averages that differ from the average of cluster 2.

AGE

Tukey HSD[a,b]

3CLU_CGPTIP	N	Subset for alpha = 0.05		
		1	2	3
3	109	1,87		
1	150		3,40	
2	141			4,03
Sig.		1,000	1,000	1,000

SPuse

Tukey HSD[a,b]

3CLU_CGPTIP	N	Subset for alpha = 0.05	
		1	2
2	141	,70	
1	150		1,00
3	109		1,00
Sig.		1,000	1,000

OCCUP1

Tukey HSD[a,b]

3CLU_CGPTIP	N	Subset for alpha = 0.05	
		1	2
1	150	,00	
2	141	,01	
3	109		1,00
Sig.		,486	1,000

OCCUP2

Tukey HSD[a,b]

3CLU_CGPTIP	N	Subset for alpha = 0.05		
		1	2	3
3	109	,00		
2	141		,45	
1	150			,99
Sig.		1,000	1,000	1,000

REG

Tukey HSD[a,b]

3CLU_CGPTIP	N	Subset for alpha = 0.05	
		1	2
2	141	2,10	
3	109		2,86
1	150		2,90
Sig.		1,000	,871

MOT

Tukey HSD[a,b]

3CLU_CGPTIP	N	Subset for alpha = 0.05	
		1	2
1	150	1,02	
3	109	1,10	
2	141		2,53
Sig.		,347	1,000

WAIT

Tukey HSD[a,b]

3CLU_CGPTIP	N	Subset for alpha = 0.05	
		1	2
2	141	,29	
1	150		,65
3	109		,76
Sig.		1,000	,107

CHAN

Tukey HSD[a,b]

3CLU_CGPTIP	N	Subset for alpha = 0.05		
		1	2	3
2	141	,33		
1	150		,54	
3	109			,71
Sig.		1,000	1,000	1,000

PTApp

Tukey HSD[a,b]

3CLU_CGPTIP	N	Subset for alpha = 0.05	
		1	2
2	141	,18	
1	150		,39
3	109		,41
Sig.		1,000	,888

Figure 37 - SPSS output for homogeneous subsets (HS) (Tukey)

Given the information illustrated above, table 12 tried to characterize the three clusters considered:

Table 12 - Characteristics of the identified clusters

User 1	Middle aged, employed, uses SP, uses PT regularly to go to work, while waiting uses both the SP and rests, uses both physical and digital channels and does not use PT apps frequently.
User 2	Older, mainly retired, uses less SP, uses PT sometimes for leisure or other affairs, while waiting rests, uses physical channels and does not use PT apps.
User 3	Younger, student, uses SP, uses PT regularly to go to school, while waiting uses the SP, uses digital channels and does not use PT apps frequently.

To assess the linear relation between features' utility variables, a Pearson correlation analysis was carried out (figure 38). The strongest correlation – 0,674 – is between **accessing schedules and ETA** (**UTsched**) and **being notified regarding service alterations** (**UTalt**). This is expected since both require real time information and when ETA are too long people want to know why. **UTop** and **UTalt** are moderately correlated as well as **UTpay** and **UTplan**. Features useful for daily users regarding disruption alerts, ETAs and cost optimization (**UTsched**, **UTalt**, **UThist**, **UTpay**) are less related to features that have to do with comfort and leisure (**UToccup**, **UTprox**). However, trip planners (**UTplan**) are useful for travels other than commuting so these are related to the leisure ones (**UToccup**, **UTprox**).

Correlation Matrix

		UTop user opinion	UTsched schedules and ETA	UTalt notify service alterations	UThist notify based on history	UTpay payments and validations	UTplan trip plan, cost and duration	UToccup vehicle occupancy	UTprox proximity cultural events
Correlation	UTop user opinion	1,000							
	UTsched schedules and ETA	,385	1,000						
	UTalt notify service alterations	,407	,674	1,000					
	UThist notify based on history	,307	,431	,480	1,000				
	UTpay payments and validations	,223	,317	,313	,307	1,000			
	UTplan trip plan, cost and duration	,231	,394	,400	,359	,485	1,000		
	UToccup vehicle occupancy	,217	,140	,184	,228	,194	,301	1,000	
	UTprox proximity cultural events	,282	,266	,297	,239	,240	,377	,305	1,000

Figure 38 - SPSS output for the correlations between UT variables

Factor analysis aims to recognize fundamental variables (factors) which describe the pattern of correlations within a set of variables. It is frequently used to reduce data and identify the factors that characterize most of the observed variance in the original variables. Figure 39 demonstrates that a 5 factors solution is rather admissible to resume the 8 original features' utility variables. The solution represents 83% of the total variance and even the worst represented variable (**UThist**) has an extraction value of 70%. The component matrix for the rotated solution tells that factor 1 is highly correlated with **UTsched**, **UTalt** and **UThis,** meaning that these three variables could be gathered into one ("access to service schedules and real time notifications"). The same happens with factor 2, highly correlated with variables **UTpay** and **UTplan** ("allows to plan the trip and make e-payments").

Communalities

	Initial	Extraction
UTop user opinion	1,000	,961
UTsched schedules and ETA	1,000	,752
UTalt notify service alterations	1,000	,772
UThist notify based on history	1,000	,696
UTpay payments and validations	1,000	,887
UTplan trip plan, cost and duration	1,000	,718
UToccup vehicle occupancy	1,000	,922
UTprox proximity cultural events	1,000	,931

Extraction Method: Principal Component Analysis.

Rotated Component Matrix[a]

	Component				
	1	2	3	4	5
UTop user opinion	,260	,096	,113	,120	,926
UTsched schedules and ETA	,799	,175	,173	-,087	,213
UTalt notify service alterations	,818	,147	,184	,000	,218
UThist notify based on history	,740	,176	-,063	,338	,002
UTpay payments and validations	,145	,917	,010	,046	,152
UTplan trip plan, cost and duration	,336	,667	,346	,190	-,062
UToccup vehicle occupancy	,065	,114	,170	,929	,112
UTprox proximity cultural events	,144	,133	,923	,160	,121

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 6 iterations.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3,304	41,298	41,298	3,304	41,298	41,298	2,082	26,019	26,019
2	1,067	13,342	54,640	1,067	13,342	54,640	1,410	17,621	43,640
3	,889	11,109	65,748	,889	11,109	65,748	1,082	13,523	57,163
4	,713	8,916	74,664	,713	8,916	74,664	1,063	13,291	70,454
5	,667	8,337	83,001	,667	8,337	83,001	1,004	12,547	83,001
6	,578	7,225	90,227						
7	,461	5,761	95,987						
8	,321	4,013	100,000						

Extraction Method: Principal Component Analysis.

Figure 39 - SPSS output for factor analysis of UT variables

ANOVA was used again to understand how different types of passengers see the new app and the features to be included. Figure 40 shows that clusters' intention of using the app in the future is not significantly different and, since the value showing in figure 30 is above 80% it is reasonable to conclude that most passengers consider using it. Regarding SUM_UT, the differences between cluster 1 and 3 are non-significant, and cluster 2 presents a lower average score.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
FUT use app future?	Between Groups	,599	2	,300	2,757	,065
	Within Groups	43,151	397	,109		
	Total	43,750	399			
SUM_UT sum per case	Between Groups	593,543	2	296,771	8,684	,000
	Within Groups	13567,967	397	34,176		
	Total	14161,510	399			

SUM_UT sum per case

Tukey HSD[a,b]

3CLU_CGPTIP	N	Subset for alpha = 0.05	
		1	2
2	141	22,48	
1	150		24,22
3	109		25,54
Sig.		1,000	,162

Figure 40 - SPSS output for ANOVA between clusters regarding FUT, SUM_UT and HS (Tukey)

3 Analysis of causal relations

Linear regression was applied to assess the effect of the three groups of passenger characteristics (GC, PT and PI) on the total score of the features (**SUM_UT**). To include the variables in the model the “Enter” method was used. Figure 41 shows that the first variables included (GC) explain 6,4% of the SUM_UT dependent variable. With the second set of variables included (PT), the percentage grows to 9,2%. The third set of variables (PI) does not represent a significant change (“Sig. F Change” > 0,05).

The coefficients table of the output shows which variables contribute significantly to the dependent variable. The first model presents two significant variables, **AGE** and **SPuse** (“Sig.” < 0,05), while from the variables added in the second model only **WAIT** excels. Thus, younger passengers who own a Smartphone and use it while waiting for transport are more positive about the future app.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	,253[a]	,064	,052	5,801	,064	5,376	5	394	,000
2	,303[b]	,092	,073	5,736	,028	3,983	3	391	,008
3	,315[c]	,099	,074	5,734	,008	1,097	3	388	,350

a. Predictors: (Constant), SPuse, GEN, OCCUP2, AGE, OCCUP1

b. Predictors: (Constant), SPuse, GEN, OCCUP2, AGE, OCCUP1, REG, WAIT, MOT

c. Predictors: (Constant), SPuse, GEN, OCCUP2, AGE, OCCUP1, REG, WAIT, MOT, SAT, PTApp, CHAN

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	24,074	1,874		12,846	,000
	GEN	-,754	,584	-,063	-1,292	,197
	AGE	-,708	,346	-,145	-2,046	,041
	OCCUP1	,967	1,202	,073	,804	,422
	OCCUP2	,463	,828	,039	,559	,576
	SPuse	2,241	1,003	,115	2,234	,026
2	(Constant)	23,358	2,993		7,805	,000
	GEN	-,745	,577	-,062	-1,290	,198
	AGE	-,349	,358	-,071	-,976	,329
	OCCUP1	,586	1,391	,044	,421	,674
	OCCUP2	-,048	1,048	-,004	-,046	,963
	SPuse	1,520	1,019	,078	1,491	,137
	REG	-,082	,501	-,010	-,165	,869
	MOT	-,269	,549	-,038	-,490	,624
	WAIT	2,211	,662	,185	3,342	,001

a. Dependent Variable: SUM_UT

Figure 41 - SPSS output of linear regression predicting SUM_UT

4.1.2.5. Results interpretation

From the characterization of the sample it is possible to conclude that commuters (active population and students) are the most regular passengers and represent the majority of the passengers. The widespread use of the Smartphone (90% of the respondents own one) and its usage during waiting times evidences that there is also a clear opportunity in using time spent in the context of travel as a tool for co-creation of value. In addition, 43% of passengers use the Smartphone to access information about transport so the results support the argument that Smartphones will be one of the most effective means of disseminating information about public transport. However, the majority does not use a mobile app to access information (they use the operators' websites) so there is room for improvement in this field. It was noticed that many people do not use transport-related applications because of their poor usability ("I do not know how to handle mobile apps" or "they are very complicated, time consuming and heavy on mobile phones") or low credibility attributed by passengers ("crash many times and displays information that does not match reality"). These arguments given by daily commuters who depend on public transport for moving in urban areas show some crucial aspects for the low levels of app membership.

Information delivery channels must keep up with technological developments and become more responsive to the immediate needs of passengers since it is possible that those who use the digital channels might be somewhat dissatisfied because they have more expectations. The paper board will be outdated in the next few years, and the first substitutes will emerge in the city centers where multimodality is most relevant.

It is also evident that some features are more useful than others and it is perceived that those considered fundamental must present high levels of performance. Next arrivals (ETA), access to timetables and warnings on disruptions are the most relevant features and are overvalued by regular commuters. Features that allow the passenger to give an opinion about the service, receive notifications according to the history and plan trips are considered useful. Throughout the collected feedback some suggestions were found relevant: as for other mobility services, many respondents referred to “rating the drivers” as a useful update of the app; via Smartphone, sending a signal to the driver on the vehicle indicating that a user with reduced mobility is waiting at the stop; after warning that a certain vehicle is late, the app should suggest relevant alternatives considering specific needs; a large number of respondents requested a light mobile app.

The high percentage of regular passengers interested in using the application and the increase in the modal split attributed to public transport (due to the monthly subscription in the MAP for €40) will force the service to respond to a larger and more demanding audience. The survey also allowed the observation of three types of passengers who use public transport in a distinct way and appreciated the value of the app's features differently. The important thing about this classification is to verify that type 1 and type 3 passengers are the most regular ones and intend to use the application because they clearly perceive its value.

4.1.3. Reflection on current situation

This section includes some reflections on information provision, information demand and good practices in well-developed cities in terms of urban mobility. According to the available channels in the MAP, some are outdated and some need improvements. Paper boards attached to bus shelters are useful when the vehicles are usually on time but less so when it comes to unforeseen events. Whereas there are many more bus stops than metro stations it might not be economically viable to install dynamic (even if low-powered) displays at all stops. Alternatively, the QR code could be associated so that the user could access the necessary information through a Smartphone. Mobile apps which are currently available have not yet reached the levels of performance desired for this purpose in terms of available information. Despite the high number of regular passengers already using their Smartphone to access information, many still do not do so through an app or are dissatisfied with the app they are using. By comparing MAP's performance with other cities, best practices in integrating technology into public transport are linked to platforms that create open data to boost innovation and to the implementation of advanced communications. However, for this to happen, policies need to be more responsive to collaboration with private initiatives and new revenue streams must be created to improve service affordability for passengers, even in the most remote areas. Digital platforms that support public transport enable the extension of the service to areas with lower affluence because people are informed in real time.

4.2. Proposal for a new concept of interaction between service provider and passenger

This project focuses on new solutions for improving the interaction between operator and passenger. The Smartphone was identified as the main tool to achieve this goal. After understanding the characteristics of the mobility system in a broader sense, arguments are presented on how an advanced mobile app would tackle some challenges and facilitate the good practices that are already implemented in the system. Here, the new concept of interaction between the passenger and transport operator is demonstrated. The concept encompasses the features to be included in the mobile app, its characteristics, technological requirements and other relevant aspects. UML diagrams were used to illustrate the user interface of the identified key features.

4.2.1. Aspects of the new concept

The present project aims to reflect on new solutions for the interaction between the service provider and the passenger. The Smartphone has been identified as the channel with the highest potential to serve this purpose, considering that it is personal (customizable), connected (updated with real-time information), accessible (widely used by the population) and has a great capacity to gather a lot of information in a single application.

These characteristics have been previously identified by others and therefore there are already many mobile applications on the market that allow for planning trips, accessing the state of the transport network in real time, purchasing tickets, etc. However, in the MAP, there is still the need to integrate these features seamlessly in one mobile application while also adding the monitoring of customer satisfaction in a systematic and inexpensive way. Hence, it would be possible to incorporate features that would benefit both locals and tourists. This concept of application would allow passengers to be transported efficiently and effectively while also contributing to the increased use of public transport. The app should present a simple interface and high standard features and for that reason both front-end and back-end development require great planning and effort. The provision of accurate information relies on the inclusion of a map platform, data from service providers, and ridership companies, along with a mobile payment platform and ticketing solutions. Today's passengers strongly value their time and expect service providers to deliver more suitable services that simplify trip planning, particularly in unfamiliar places. A versatile and seamless app must be a map, trip assistant, ticket vending machine and a pocket tour guide (AltexSoft 19/10/2018). Vehicle tracking features are also useful when including all accessible modes. The context in which the mobility app is used determines its assessment of utility since it assists both passengers who need to find a particular location and daily commuters who need disruption alerts and favourite locations by using the best alternative to reach the destination. This implies that there are different types of users according to context and personal characteristics and app UX (user experience) must consider this fact when designing the features.

Figure 42 is presented to distinguish three types of public transportation apps.

Navigation apps	Service provider apps	Tour apps
Are adapted to different cities considering the map and information provided by the transport operators. These are intermodal and allow access to real-time information in an integrated way to facilitate trip planning.	Are customized to the service operator and, despite allowing travel planning for the operator concerned exclusively, these enable the reservation and payment of tickets.	Enable flexible access to tourist transport by allowing users to access available tourist routes (where they can hop-on and off at specific landmark stops), maps with points of interest, timetables, audio guides, etc.

Figure 42 - Different types of public transportation apps - based on AltexSoft 19/10/2018

The ANDANTE network represents the integration of tickets in the MAP, meaning that most of the metropolitan transportation modes use the same ticketing system. This facilitates the aggregation of a trip validation feature into the application because only one ticketing system needs to be integrated. The ANDA app integrates this system digitally while allowing users to access the modes with their Smartphone. ANDA uses an algorithm to calculate the cost of the trip according to the operative zoning system therefore, there is no need to purchase any ticket when using the app. The new proposed concept intends to integrate ANDA, mostly as it is.

Since public transportation apps are now part of peoples' everyday lives and there are several categories of information and actual use of the public transportation system, it is necessary to create a seamless user experience. To be competitive, the app must integrate a set of features that truly made commuters' lives easier.

The App System is based on three main aspects: mobile e-payments, trip management (encompasses all the required information for trip-related requests) and assessment of customer satisfaction. The package diagram presented in Fig. 43 represents these main aspects and defines the relationships between them. Also, it provides a modular perspective on the system's dynamics and interactions.

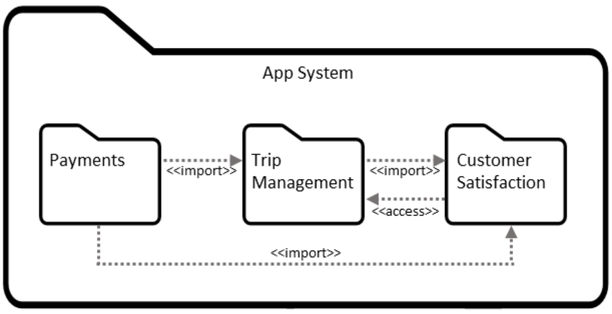


Figure 43 - App system package diagram

Table 13 presents the classes assigned to each package to understand what kind of information is associated with which module.

Table 13 - App system classes and respective packages

Package	Associated classes			
Payments	Payment Method	Payment		
Trip Management	Stop	Route	Vehicle	Schedule
	Trip	Trip Segment	Service Provider	Notifica-tion
Customer Satisfaction	Passen-ger	Driver	Survey	

To enable a deeper understanding regarding the system's interactions, the class diagram in Fig. 44 demonstrates the different classes necessary to provide information to the user.

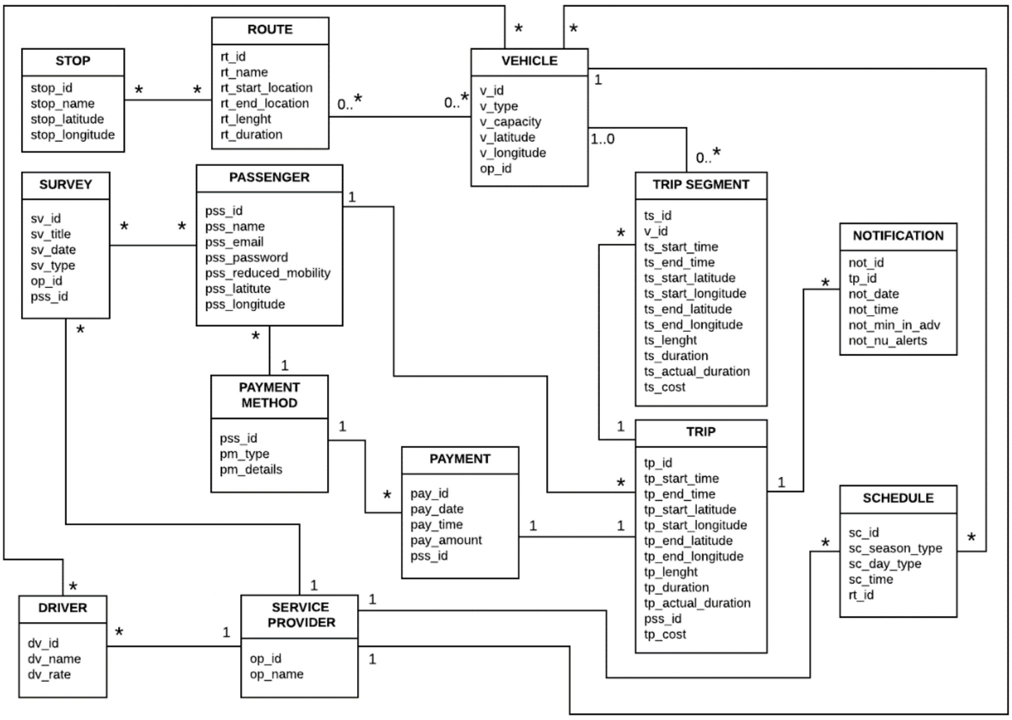


Figure 44 - App system class diagram

This diagram is more focused on the requirements of information, user transactions, trip-generated information and user experience rather than on the technicalities and programming. Each trip has an associated cost that is linked to a required e-payment. Payments require the passenger to define a payment method. Payments are requested and collected upon different types of service utilization since these could be monthly packages, on-the-go or special tickets such as 24-hour tours. Classes such as stop, route, vehicle and schedule are fundamental to provide both real time and planned information on travel necessities. Trip and trip segment use the actual position of the vehicle to enable the provision of accurate travel alternatives according to users' needs. These alternatives include real time information on the network's performance but might also include planned disruptions and maintenance works to plan trips ahead. These sets of features are personalized in agreement with the filters available when planning a trip.

Service providers such as transport operators can upload surveys to the platform and describe the population sample so the system can recognize users accordingly. After recognizing specific users, the system displays a notification that offers the opportunity to answer to these surveys in exchange of some kind of benefit to the user to reward them for co-creating value. Another important characteristic of the this concept is that it aims to add value to the data generated by users, on the basis of anonymity, (such as travel patterns, bottlenecks, surveys, etc.) and apply data analysis to it to generate knowledge around the network to provide more valuable services.

From the developed work so far and according to the results of the survey conducted there are several features that are considered most relevant for daily commuters and others that need to be integrated to add value to free apps to attract more cities and service providers to deploy such technology. Instead of just providing information to the public the app creates a two-way interaction where users can answer surveys and generate valuable data for the service providers.

The use case diagram presented in Fig. 45 demonstrates the key features to be implemented in the app. These represent the core aspects to be covered regarding information and how to what it properly. For instance, the app should also include information on disruptions and suggest the fastest routes as well as places nearby and show routes accordingly. When planning a trip, it should include the connections between different modes and show which ones are available while letting the user choose from them. It should enable saved locations and routes and them to be shared. Nowadays and reinforced by tourism, it is necessary to enable different digital payment methods that better suit each user as well as providing card scanning mechanisms and QR codes for tickets. Vehicle tracking features are useful to display the real position of the vehicle while the user is waiting or during the trip. Arrival and disruption notifications enable the user to plan their journey with time and choose the new alternatives proposed by the system, these notifications return the control over to the user. Also, in order to retain more users over time, it is smart to apply gamification and add loyalty elements.

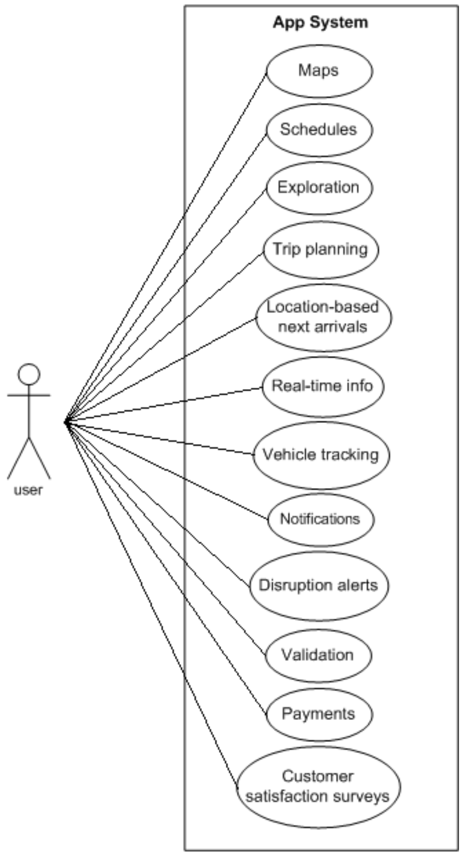


Figure 45 - App system use case diagram

4.2.2. Mobile application features

This section illustrates the most important use cases by presenting their sequence diagram and mock-up to facilitate the user experience perception. The mock-up of the application was created from the design of already existing apps (like Google Maps and the Transit App). Since there are already well-developed solutions in this area, the goal is to improve them and to provide a better user experience.

The feature presented in Fig. 46 refers to **location-based next arrivals** and demonstrates arrival times at stops closest to the user's location. To favorably condition the alternatives returned by the system, the user can choose the type of transport they intend to use. After choosing the mode and the trip, when the system recognizes that the user starts the journey, it shows the route followed with vehicle tracking. This second screen shows (by default) the next three departures of this route to the nearest stop of the user as well as all the following stops and respective intermodal options. When the system detects that the user has left the route it sends a notification so that the user can evaluate the trip according to the parameters shown.

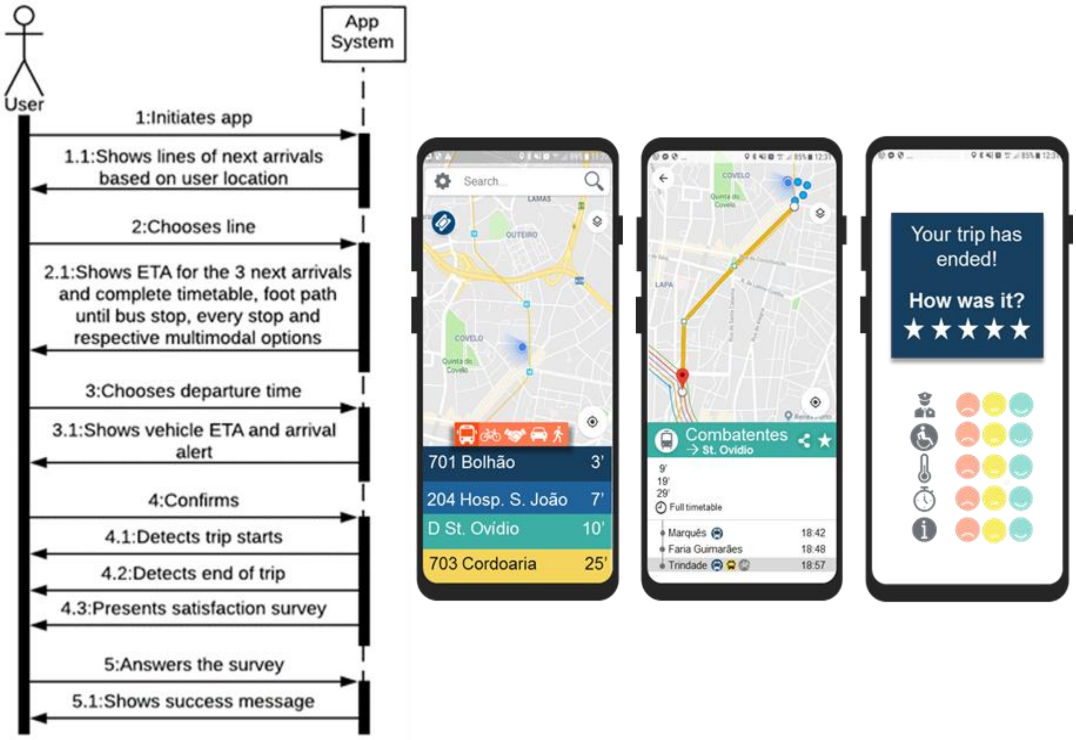


Figure 46 - Location-based next arrivals: sequence diagram and mock-up

The next feature indicates **trip planning** (Fig. 47). It allows the user to start the search from the home screen by indicating the desired destination. The system returns the name and an image that identifies the destination (so that the user validates it) and presents the options of "directions", "save in favourites" or "to share". By clicking on "directions", the system displays a screen similar to Google Maps for that purpose. The user can choose different types of transport. The system returns by default the fastest route, but the user can select in the options if they want the cheapest route, with fewer connections, with less time on foot, etc. It can also indicate the time for which you want to start the trip and the system indicates the weather forecast. The user can choose a different starting point than the current location. The system then returns the best alternatives depending on the user's conditions by indicating all the necessary ways from A to B, start time and end (expected), the duration and cost and also the time of arrival of the vehicle to the destination. The user chooses the alternative that best suits his/her needs and the system shows the entire route on the map, the sections on foot, the duration of each section, etc. When the user clicks on the "check" to confirm, in case the system acknowledges that the trip is planned, a notification pops-up for the user to indicate if they want to be notified “x” minutes before the scheduled trip begins.

Figure 47 - Trip planning: sequence diagram and mock-up

Figure 48 represents the **notifications** feature, either from a scheduled alert or from a service alteration. It is a consequence of the previous feature. When the system recognizes that there is a scheduled trip within minutes it sends a notification exemplified by the first screen. The system updates the notification by considering the status of the trip: arrival at the stop, number of stops to the destination, vehicle exit warning and way to destination. The notification also updates the remaining time to the destination, which vehicle should pick up and presents a time bar for user experience purposes.

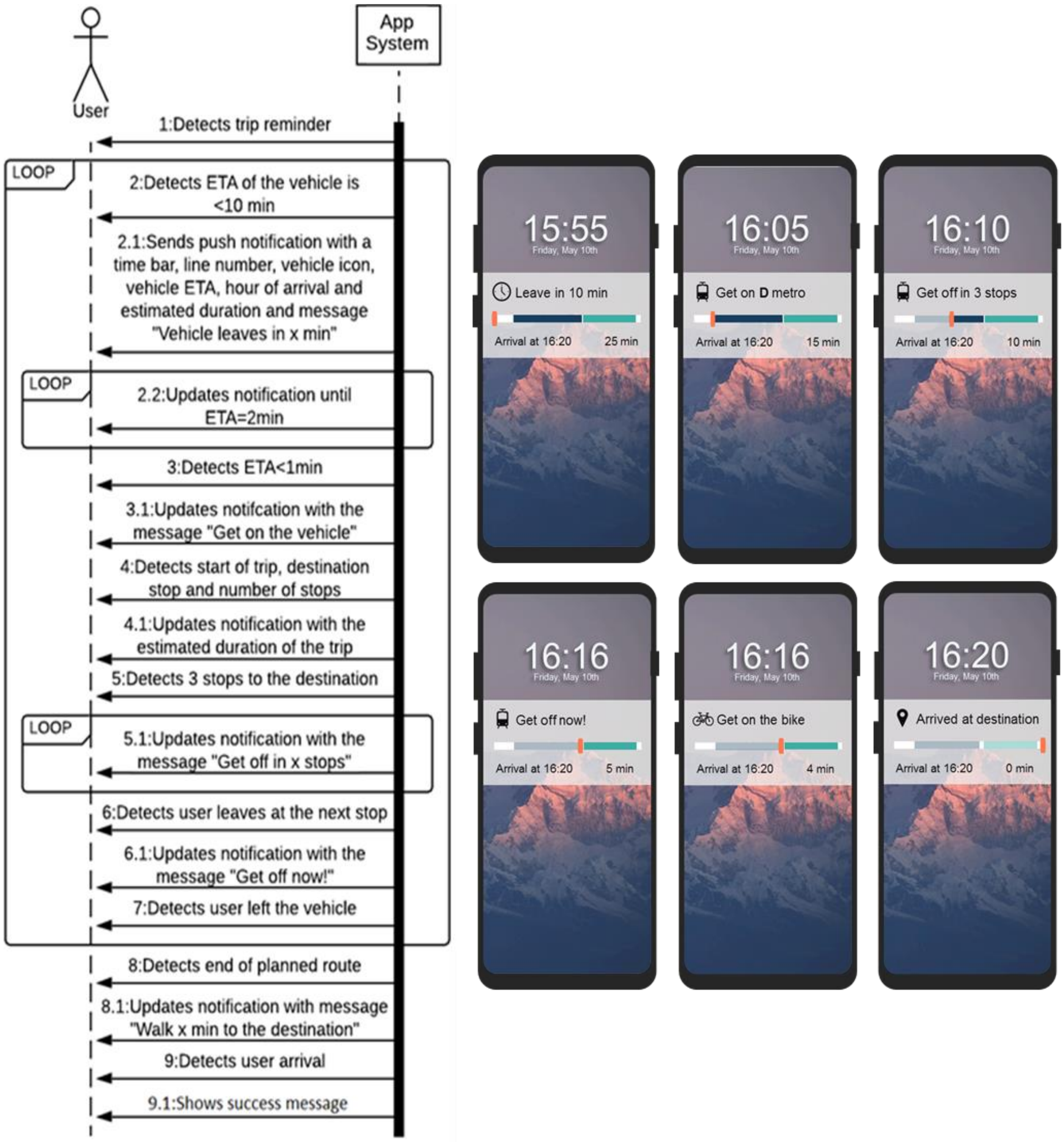


Figure 48 - Notifications: sequence diagram and mock-up

Figure 49 concerns **payments**. The main screen presents a “tickets” icon in the upper left corner. When clicking, the system opens a screen that is similar to ANDA app, however, a second "tickets" icon is added so that the user can access this feature. There are different ways of using the service, for example, the "on-the-go" method allows users to use the service continuously only having to indicate a payment method (with an associated card or account) and validate whenever the service is used. To purchase a specific ticket from the app, the user opts for a ticket and the system presents the respective information and the option of "purchase". After selecting “purchase”, the system displays different payment methods. This option also includes the possibility of card scanning to enhance the user experience. After the validation of the payment, the ticket is active from the moment it is validated at the terminal/ vehicle and is stored in the "inspection" icon so that it can be verified.

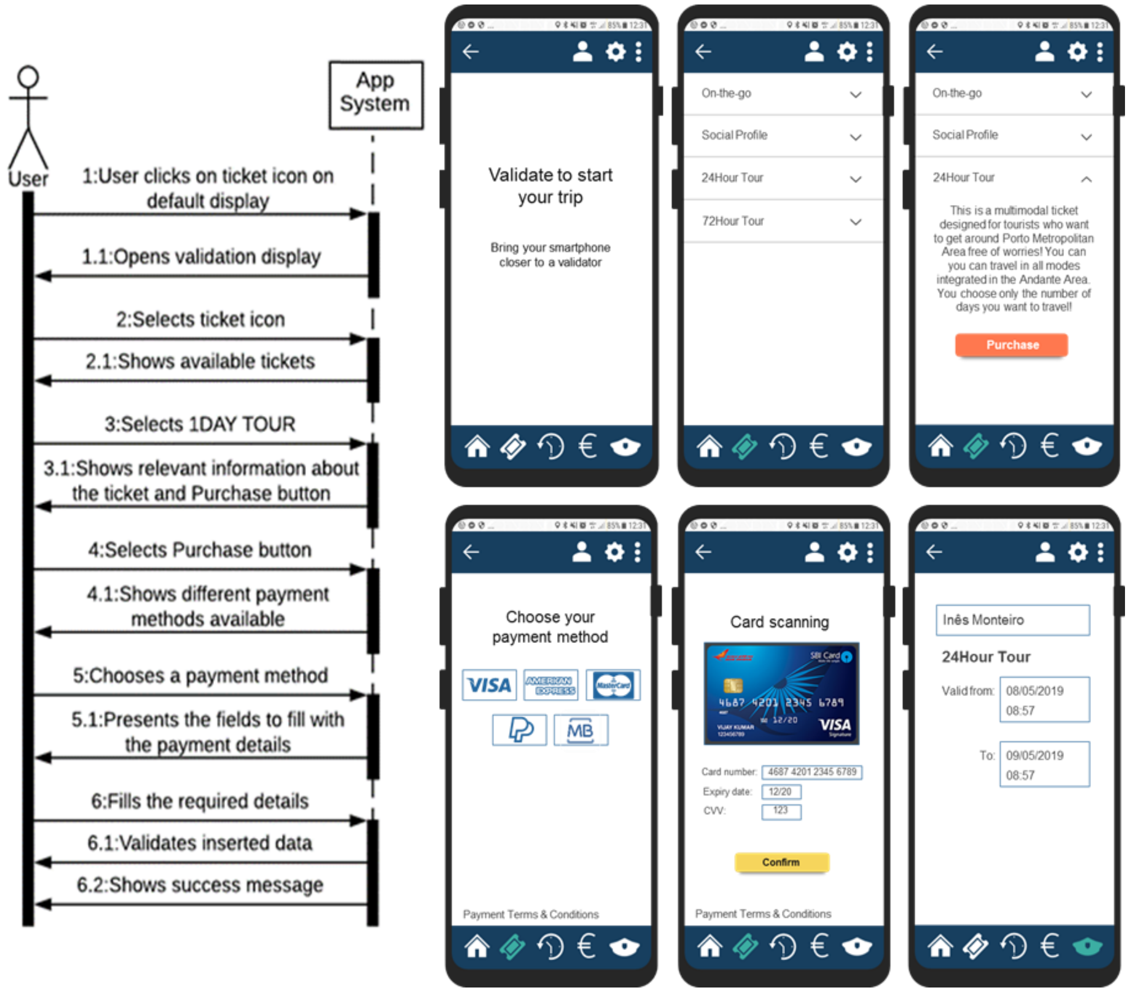


Figure 49 - Payments: sequence diagram and mock-up

This last feature, **customer satisfaction surveys** (Fig. 50), presents a high level of differentiation and integration in relation to the other apps since it allows the collection of user feedback in a more systematic and inexpensive way. The process begins when the system recognizes the survey request by a service provider. The system analyzes the sample to be considered and recognizes (anonymously) the users that match the characteristics necessary to respond to the survey and sends an inviting notification. When the user clicks the icon, the system presents a brief description of the survey and the benefits of responding. The user can always refuse. The survey is presented and the responses are automatically sent to a database so that the necessary statistical treatment can be applied.

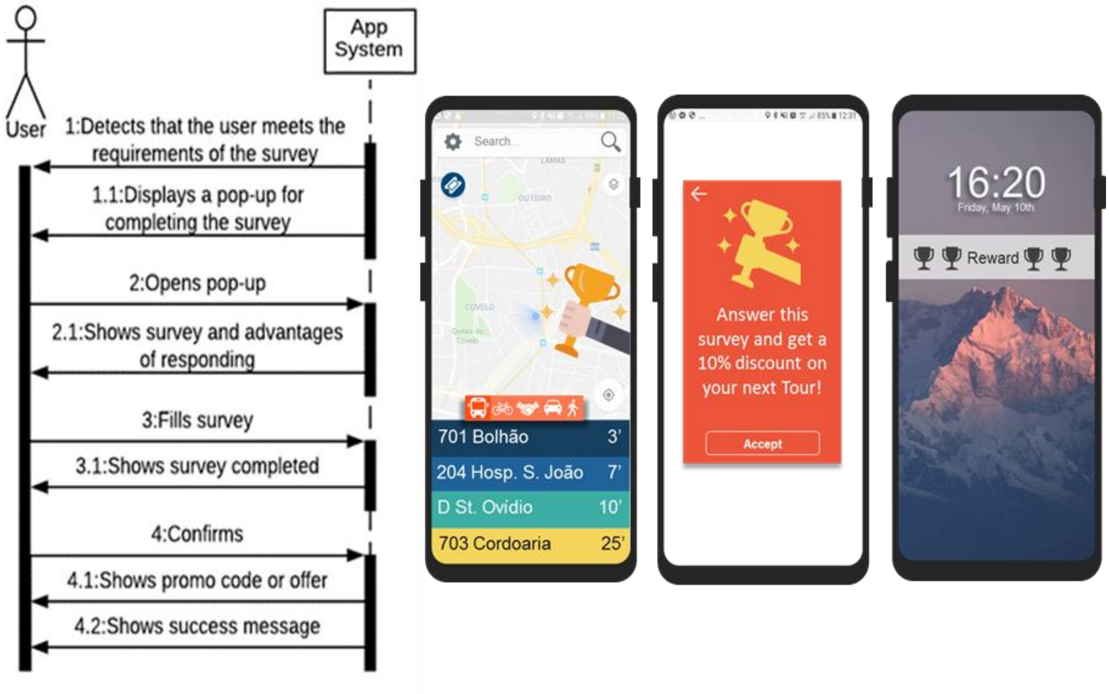


Figure 50 - Customer satisfaction surveys: sequence diagram and mock-up

4.2.3. Technological aspects

Table 14 represents some of the key technologies that could be useful to implement in such a system.

Table 14 - Technological aspects - based on AltexSoft 31/01/2019

Feature	Technology	Description
Maps	Maps SDK Maps Static API Maps JacaScript API	By integrating Google Maps data into the app, it is possible to access its servers, data download map display and response to map gestures while also including both static and interactive maps.
Schedules and routes	General Transit Feed Specification (GTFS)	Service providers generate and post digital timetables so developers can use this information (routes, stops and timetables) to supply transit apps.
	GTFS Realtime	By also sharing the current status of vehicle location it is possible to access real time information on departures, arrivals, disruptions and congestion levels.
Vehicle tracking	Vehicle Location Systems (AVLs) and Advanced Transportation Management System (ATMS)	These provide overall control over operations since it is possible to track the geographical location of the fleet, speeds and directions based on GPS coordinates.
Trip planner	Directions API Distance Matrix API Geocoding API Geolocation API Places API	This set of APIs provide optimal routes by calculating directions between locations for different transportation modes, route distance and travel times. It is also possible to convert addresses into GPS coordinates (and vice-versa), provide an accurate location of an equipment using Wi-FI and information about relevant places.
Mobile payments and tickets	Mobile ticketing system	It is a client-server system that requires an equipment with the app installed, a server and a scanning device. The user can scan a ticket on a validation device or merely activate it using the app.
	Ticket validation technologies	Ticket activation can be performed by numerous contactless communication technologies such as NC (Near Field Communication that uses radio frequency), BLE (Bluetooth Low Energy) and Wi-Fi aware. There are already platforms that turn SP into ticketing machines using barcodes or QR codes and digital wallets. These platforms also enable access to back-office cloud services which include reporting, transit-data management, customers service request processing, monitoring and validation functionalities.
	Mobile ticketing platforms	Integrating a payment processing platform also enables cashless payment processing, data analytics and reporting and fraud detection.
Other	Frequent trips	Enable service customization.
	Offline traffic maps	Provide detailed maps regardless the internet connection.

4.3. App as a commercial product

The challenge proposed by OPT eventually led to the identification of some issues related to the applications available on the market. There is no integration or if there is, the user experience they offer is not the best. This new app concept aims to bridge this gap and create a mobility experience that integrates all the functionalities needed to meet the basic mobility requirements (know which services are available, pay for the service and provide service assessment creating valuable feedback for the service provider). Thus, Fig. 51 presents a loop to reveal the interdependencies between the main stakeholders of this dynamic. Despite the commercial character of this section, this analysis does not constitute a business plan sufficiently substantiated to be evaluated as such.

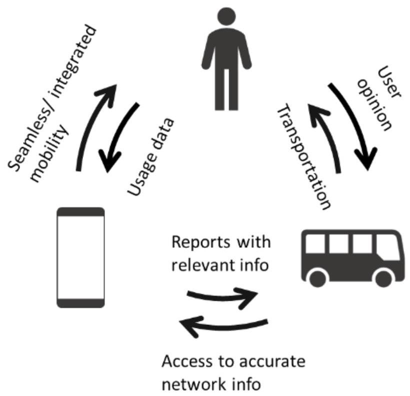


Figure 51 - Interactions between most relevant stakeholders

4.3.1. Innovation strategy

To create an innovative product in a market where there are already some mobile apps developed by major companies in the sector of mobility, OPT must assess the degree of innovation of the proposed concept. From the identification of the challenges addressed by the app – features' integration and acquisition of customer feedback in a systematic way through the app – it is possible to identify the differentiating elements and the definition of new market boundaries.

Based on the Blue Ocean Theory (BOS), the app's innovation strategy relies on the agreement with the indicators advocated by this strategy. There are several differentiating elements on this app, however, some are more obvious than others and perceived by service users and service providers differently. This application intends to present a product that combines the most important functionalities by aiming for value co-creation and continuous interaction between stakeholders. In addition, it brings together the three types of app and uses the data generated from using the services to create knowledge about the needs of the user.

Another relevant aspect is the fact that the app meets the premise *instead of trying to get more exclusive market niches, the ideal is to understand what unites non-users and create innovation around it*, this means that it is possible to defragment the concept of clusters and realize what the "whole" needs. Figure 52 demonstrates the value cycle of the system.

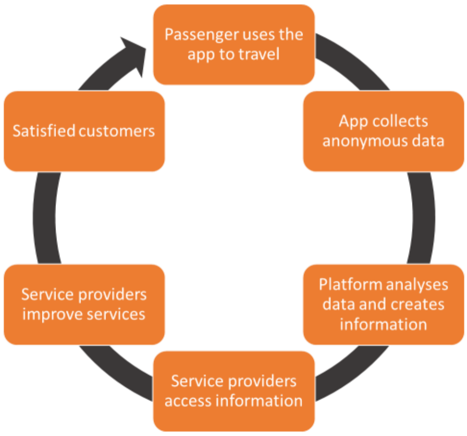


Figure 52 - System's value creation loop

The development of a low cost innovation is carried out through the LS principles, which, by advocating the creation of a minimum viable product (MVP) that can be tested with the users in order to incrementally improve and to add features in a modular way, makes is possible to optimize resources efficiently and comply with users' requirements.

Creating a new demand begins with identifying the problem of passengers not traveling seamlessly through the network and having to use various applications or other tools to interact with the system, and vice versa. Then, given the new legislation on customer satisfaction in PT, this concept creates a new market for service providers as clients of the app, since the remote collection of customer feedback allows the systematic and inexpensive monitoring of users' satisfaction towards the service offered. This new demand expands the market boundaries which, despite the existence of many mobile applications, by including the most relevant features distinguish OPT from the rest. This means that OPT can operate in a market of its own, based on the co-creation of value among the stakeholders. The objective is to enhance the performance of the transport network and improve the perception of the quality of the service in an economically viable way, thus promoting the use of public transport.

Product, customer and marketing analysis make it possible to monitor the viability of innovation as a product itself. The app must deliver the value it promises (seamless mobility) and must follow a customer-oriented philosophy where there are value-based partnerships. The ways it is being tested and finally distributed to the public are also very important for effective diffusion. This monitoring is also part of the innovation because adding the differentiation with the low cost creates innovation value.

4.3.2. Business strategy

In the mobile app industry, a Lean Startup (LS) approach to the business strategy is more appropriate compared to elaborating a business plan (BP). A BP is more useful in stable/predictable markets, but it is still relevant in more advanced stages to refine the product planning process. According to Kostecki (15/01/2015), "Blue Ocean answers "what to do?", while Lean Startup answers the question of "how to do it?". LS isn't about changing a market incrementally, it can be about building a brand-new market (a blue ocean) using an incremental technique to hedge against risk." To address the uncertainty related to this type of technology, a smart strategy must focus on testing iteratively with potential customers to reduce risks and costs. By reducing uncertainty, it is possible to apply management techniques to successfully deliver a product to a customer and according to their needs and through testing, it is easier to perfect a vision faster according to a specific methodology.

When focusing on developing an MVP and applying the BML loop it enables the establishment of customers even before the product app is launched because by involving possible users they engage with the value creation process and it is in their best interest that the product suits their needs, as they need it. The conduction of the survey allows the drawing of conclusions as far as the features to be included in the app, however, by resorting to innovators and early adopters it is possible to create innovative solutions by ensuring that they will be the drivers of innovation and will help to improve the app iteratively by following the process. Type 3 users (survey analysis) are tech-motivated and are willing to test and support the co-creation process but, most importantly, these are regular users of public transport. This means that if users are engaged with the app, they are more likely to use it and generate more data while being eager to receive more updates. The key factor is to retain users and involve them in the value creation process. Based on the aspects for the adoption of innovation, the user must clearly perceive the relative advantage over competitors' apps. The app must be compatible with the users' beliefs and therefore the choice of colors and graphics should be adequate. It must also be easy to install, test, and use to ensure that it gets to be used by as many passengers as possible who are prepared to use it continuously.

As the project progresses, the validated learning principle optimizes the planning process as it promotes value creation based on what customers are willing to pay for by mitigating the need to create elaborate beta versions that may not meet the needs of stakeholders in the best way. It is, therefore, important that each incremental change is evaluated to verify its suitability and for this it is essential to make innovation accountable and, measure progress, set goals and know how to prioritize tasks.

Finally, regarding the value perceived by transport operators, the analytics applied to data generated from the app users must be defined together with the service providers so they can give input on what they actually need regarding user information. By doing so, it might soon reduce the need for mobility surveys and other complex and expensive types of surveys.

The Lean Canvas (LC) template presented in Fig. 53 is widely used in the LS context since it provides a quick and macro view of the application's business strategy. The LC presents the main aspects of the product development and triggers a starting point for the planning of the app as a commercial product.

<table>
<tr>
<td rowspan="2">PROBLEM
Lack of app integration towards seamless mobility

Lack of automatic solutions to collect and analyze customer feedback

Poor user experience

EXISTING ALTERNATIVES
Google Maps
Moovit
Citymapper
MOVE-ME
Transit</td>
<td>SOLUTION
App that integrates transit features with e-payments and customer satisfaction surveys

Advanced analytics to generate valuable info</td>
<td rowspan="2">UNIQUE VALUE PROPOSITION
All the features needed for seamless and optimized mobility in one simple app

Value-added services based on customer feedback analysis to improve network quality

HIGH-LEVEL CONCEPT
Better and cheaper mobility services based on information systems</td>
<td>UNFAIR ADVANTAGE
Pre-established partnerships with transport operators

Know-how</td>
<td rowspan="2">CUSTOMER SEGMENTS
PT passengers
Overall commuters
Transport operators
Municipalities

EARLY ADOPTERS
Students
Tech fanatics
Modern urban commuters</td>
</tr>
<tr>
<td>KEY METRICS
Search requests
Retention rate
Completed trips
Transaction fee through app
survey response rate</td>
<td>CHANNELS
Mobile app
Mobile app stores
Social media
Email</td>
</tr>
<tr>
<td colspan="3">COST STRUCTURE
App system development
Human resources
Data acquisition
Maintenance
Platform development
Third party APIs
Payment processing costs</td>
<td colspan="2">REVENUE STREAMS
App is free
Data generated by the app
Advanced analytics services
Information platform</td>
</tr>
</table>

Figure 53 - Lean Canvas

The SWOT analysis is presented in Fig 54. It points out the weaknesses and threats to success so that the company can improve or tackle specific challenges throughout the project.

STRENGTHS	**WEAKNESSES**
Includes 3 types of mobility apps Developer know how from developing MOVE-ME Pre-established partnerships Customer surveys and data analysis – experience The Law	Value is difficult to perceive by customers Free app Opportunity cost of developing the new app Open data platforms are not accurate Dependence on third-party information
OPPORTUNITIES	**THREATS**
New solution that will serve better than others Promotion of PT (development grants) Scalability Integration with other platforms for advanced analytics	Start from zero Competition is growing Modal split in Portugal

Figure 54 - SWOT analysis

5. Conclusions

5.1. Summary of the contribution

The conceptual nature of this project allowed the creation of a framework to develop an integrated information platform for public transportation. The goal was to create a solution that integrates aspects relevant to personal mobility, from immediate transportation alternatives to e-payments, trip planning and user feedback.

Since the methodology included assessing the current supply and demand situation (survey) regarding information and combining this practical knowledge with theoretical notions, it was possible to create a concept that integrates the most relevant functionalities for the passenger and create value from the data generated by the use of the service.

For future purposes, the classification of passengers into three types can be advantageous in determining marketing campaigns, new features to integrate and to better understand the mobility patterns of each group.

The acceptance that the Smartphone is the best alternative for information dissemination and acquisition in this sector shows that the user experience must be improved to engage users and to facilitate the use of the mobility service as a whole (MaaS). The mock-up was created based on this perspective.

Finally, the business model enables the creation of a revenue stream from an application that will be free to users but, their usage data and satisfaction surveys can be analysed and reported to service providers and other entities so that the customer service can be improved.

The contribution related to the academic studies in the area of Industrial Engineering and Management is linked to the broadening of the horizons of this school insofar as it explores a current theme with a perspective of sustainability while aiming to create a business according to management principles taught and explored.

For society, an initiative such as the one presented here would serve to improve the quality of life of the population by making the public transport service a continuous accessibility in which the user has the last word regarding personal mobility.

By promoting the efficient use of public transport, this project also contributes to environmental sustainability.

For the company, the app might be able to give continuity to MOVE-ME in a more personalized version and with more features that, in fact, facilitate the circulation of passengers in the MAP. The creation of a business strategy also highlights the benefits of developing a project of this nature.

5.2. Reflection on the developed work

The analysis of the current situation made it possible to perceive the gap between supply and demand and to verify that paper boards (previously existing at all stops) are outdated which contributes to unsatisfied users.

The conceptual development of the application aimed to align both perspectives so that the customer is more satisfied with the information and the transport operator can collect value from this interaction.

The application of advanced data analysis also allowed for drawing more precise conclusions and for perceiving the interaction between the variables that characterized the survey.

As explained previously, the research did not focus on technological requirements, and therefore, certain statements may not be easily implemented due to a lack of hardware and software development. Therefore, UML diagrams were used to present a more technical language regarding what features to implement and how these will interact. It was also not possible to create a real prototype to perform tests, but the features found most relevant to users were depicted.

The core values of this project are based on the user experience, customer satisfaction acquisition and the value created for the operator.

Regarding the business model, this did not encompass a quantitative analysis of market research and does not include other "numbers" that would have been interesting to examine.

5.3. Future perspectives

It would be interesting to continue to develop the business model and prepare a business plan accordingly.

Considering this is a conceptual project, it would also be interesting to develop in parallel an autonomous system that integrates survey knowledge and analyses mobility patterns, thus mitigating the need to conduct mobility surveys in the various districts.

This platform could also, by knowing the real position of the vehicles, modelling the network and combining this information with the use of the service and identifying bottle necks, critical zones, etc., to provide a more interesting product to the service providers.

In this way, we could also create consulting services linked to this system and finally improve the service provided to the final customer and ultimately the quality of life of the population while contributing to a sustainable future.

It is also interesting to refer the importance of adapting and scaling this platform to other cities, reinforcing that this application should be developed to be flexible and adaptable modularly.

References

Aguilera, Anne; Boutueil, Virginie (2018): Urban mobility and the Smartphone. Transportation, travel behaviour and public policy. 1st: Elsevier.

AltexSoft (19/10/2018): Public Transportation Apps' APIs and Platforms: Maps, Scheduling, Trip Planning, and Mobile Ticketing. Available online at https://www.altexsoft.com/blog/engineering/public-transportation-apps-apis-and-platforms-maps-scheduling-trip-planning-and-mobile-ticketing/

AltexSoft (31/01/2019): Best Mobile User Experience Design Practices for Public Transportation Apps. Available online at https://www.altexsoft.com/blog/mobile/best-mobile-user-experience-design-practices-for-public-transportation-apps/

Alves, David; Martinez, Luis M.; Viegas, José M. (2012): Retrieving real-time information to users in public transport networks: an application to the Lisbon bus system. In Procedia - Social and Behavioural Sciences 54, pp. 470–482. DOI: 10.1016/j.sbspro.2012.09.765.

AMPorto (2019): Home page. Available at http://portal.amp.pt/pt/, checked on 26/06/2019.

Bachok, Syahriah; Maksid, Noor Hafiza Mohd; Yaacob, Noor Alyani; Paiman, Tuminah; Razak, Sarah Abdul; Osman, Mariana Mohamed (2011): Passengers' perception of public transport information systems. In Proceedings of the Eastern Asia Society for Transportation Studies 8.

Bosch (11/21/2017): Bosch solutions for urban mobility. Connected mobility. Ebberg, Joern, Joern.Ebberg@bosch.com. Available online at https://www.bosch-presse.de/pressportal/de/en/bosch-solutions-for-urban-mobility-134144.html.

Corwin, Scott; Pankratz, Derek M. (2017): Forces of change: the future of mobility. Future of Mobility. Available online at https://www2.deloitte.com/content/dam/insights/us/articles/4328_Forces-of-change_FoM/DI_Forces-of-change_FoM.pdf, checked on 2/18/2019

Dixon, Simon; Bornstein, Justine; Irshad, Haris; Pankratz, Derek M. (2019): The 2019 Deloitte city mobility index. Gauging global readiness for the future of mobility.

European Commission (2011): A Roadmap for moving to a competitive low carbon economy in 2050. Brussels. Available online at http://www.cbss.org/wp-content/uploads/2012/12/EU-Low-Carbon-Road-Map-2050.pdf, checked on 2/20/2019.

European Environment Agency (2018): Greenhouse gas emissions from transport. Available online at https://www.eea.europa.eu/downloads/cb6580efad3f433cad10cbb9962400ad/1543568660/transport-emissions-of-greenhouse-gases-11.pdf, checked on 2/18/2019.

European Parliament, Council of the European Union (2016): Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC

(General Data Protection Regulation). In Official Journal of the European Union. Available online at https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex:32016R0679, checked on 4/3/2019.

Ferris, Brian; Watkins, Kari; Borning, Alan (2010): OneBusAway: results from providing real-time arrival information for public transit. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. ISBN 9781605589299.

Foth, M. (2009): Handbook of research on urban informatics: The Practice and Promise of the Real-Time City. Hershey: Information Science Reference. ISBN: 9781605661520.

Gleave, James (2017): Customer service standards in a MaaS future. Transport Futures. Available online at https://transportfutures.co/customer-service-standards-in-a-maas-future-2a2f90d41a0b

Goodall, Warwick; Fishman, Tiffany Dovey; Bornstein, Justine; Bonthron, Brett (2017): The rise of mobility as a service. Future of Mobility (20). Available online at https://www2.deloitte.com/content/dam/Deloitte/nl/Documents/consumer-business/deloitte-nl-cb-ths-rise-of-mobility-as-a-service.pdf, checked on 2/19/2019.

Gustavo (2009): Introdução a UML. DEVMEDIA. Available online at https://www.devmedia.com.br/introducao-a-uml/6928

Isa, Hazril Bin Md; Ismail, S. M. Sabri S. M.; Tajedi, Noor Aqilah Ahmad (Eds.) (2013): Passenger information systems for public transport in Klang City, an overview. Malaysian Universities Transport Research Forum Conference. Bangi, Malaysia, 23-24 December.

Israel, Glenn D. (1992): Determining sample size, checked on http://sociology.soc.uoc.gr/socmedia/papageo/metaptyxiakoi/sample_size/samplesize1.pdf.

Kamargianni, Maria; Li, Weibo; Matyas, Melinda; Schäfer, Andreas (2016): A critical review of new mobility services for urban transport. In Transportation Research Procedia 14, pp. 3294–3303. DOI: 10.1016/j.trpro.2016.05.277.

Kim, W. Chan; Mauborgne, Renée (2015): Blue Ocean Strategy, Expanded Edition: How to Create Uncontested Market Space and Make the Competition Irrelevant. Harvard Business School Publishing Corporation

Kostecki, Jakub (15/01/2015): Jakub Kostecki's Answer to "Is lean startup methodology inherently contradictory to the blue ocean strategy (or the Zero to One strategy)?". Quora. Available online at https://www.quora.com/Is-lean-startup-methodology-inherently-contradictory-to-the-blue-ocean-strategy-or-the-Zero-to-One-strategy

Law no. 52/2015 of June 9th. Legal Regime of the Public Transport Service of Passengers. Diário da República no. 111/2015, Series I of 2015/06/09. Assembleia da República. Lisbon Available at: https://data.dre.pt/eli/lei/52/2015/06/09/p/dre/pt/html

Lyons, Glenn (2018): Getting smart about urban mobility: aligning the paradigms of smart and sustainable. In Transportation Research Part A: Policy and Practice 115, pp. 4–14. DOI: 10.1016/j.tra.2016.12.001.

Mackett, Roger L. (Ed.) (2013): Reducing car use in urban areas. Sustainable transport for chinese cities. Great Britain: Emerald (3). Available online at https://www.researchgate.net/publication/290767184_Reducing_Car_Use_in_Urban_Areas, checked on 2/18/2019.

McKerracher, Colin; Orlandi, Itamar; Wilshire, Michael; Tryggestad, Christer; Mohr, Detlev; Hannon, Eric (2016): An integrated perspective on the future of mobility. Available online at https://www.mckinsey.com/~/media/mckinsey/business%20functions/sustainability%20and%20resource%20productivity/our%20insights/an%20integrated%20perspective%20on%20the%20future%20of%20mobility/an-integrated-perspective-on-the-future-of-mobility.ashx, checked on 2/21/2019.

mpt - mobilidade e planeamento do território (2016): Plano de ação de mobilidade urbana sustentável da Área Metropolitana do Porto – Relatório final. Available at http://portal.amp.pt/media/documents/2016/12/06/relatorio_final_pamus_amp_MuztgqN.pdf

Nishadha (30/04/2019): UML Diagram Types Guide: Learn About All Types of UML Diagrams with Examples. Cinergix. Available online at https://creately.com/blog/diagrams/uml-diagram-types-examples/

Nunes, António A.; Galvão, Teresa; Cunha, João Falcão e. (2014): Urban public transport service co-creation: leveraging passenger's knowledge to enhance travel experience. In Procedia - Social and Behavioural Sciences 111, pp. 577–585. DOI: 10.1016/j.sbspro.2014.01.091.

PORDATA (2018a): População residente, estimativas a 31 de dezembro. Available at https://www.pordata.pt/DB/Municipios/Ambiente+de+Consulta/Tabela, checked on 06/11/2018

PORDATA (2018b): População residente do sexo feminino, média anual: total e por grupo etário. Available at https://www.pordata.pt/DB/Municipios/Ambiente+de+Consulta/Tabela, checked on 06/11/2018

PORDATA (2018c): População residente do sexo masculino, média anual: total e por grupo etário. Available at https://www.pordata.pt/DB/Municipios/Ambiente+de+Consulta/Tabela, checked on 06/11/2018

Ries, Eric (2011): The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses. Crown Business. ISBN 0307887898

Rogers, Everett M. (1983): Diffusion of Innovation: Free Press. Available online at https://teddykw2.files.wordpress.com/2012/07/everett-m-rogers-diffusion-of-innovations.pdf.

Šarić, Slavko; Peraković, Dragan; Kušan, Irena (2012): Possibility of improving passenger information system in bus transport using cloud services: Development, pp. 241–249.

Sarkar, Pradip K.; Jain, Amit K. (Ed.) (2018): Intelligent transport systems: PHI Learning Private Limited. Pp. 296-299

SmartDraw (2019): UML Diagram. Available online at https://www.smartdraw.com/uml-diagram/#whatIsUML, checked on 6/5/2019

Wani, Tahir A.; Ali, Saiyed Wajid (2015): Innovation diffusion theory review & scope in the study of adoption of Smartphones in India. In Journal of General Management Research 3 (2), pp. 101–118.

Watson, Andrew (2008): Visual Modelling: past, present and future. Object Management Group. White paper UML Resource Page

Zwass, Vladimir (2010): Co creation: toward a taxonomy and an integrated research perspective. International Journal of Electronic Commerce

Appendix – Questionnaire

1. **Linha** *
Marcar apenas uma oval.
- Transdev
- Valpi
- STCP
- Metro Porto

2. **Género** *
Marcar apenas uma oval.
- feminino
- masculino

3. **A que faixa etária pertence?** *
Marcar apenas uma oval.
- 15-19
- 20-24
- 25-44
- 45-64
- +65

4. **Qual é a sua ocupação?** *
Marcar apenas uma oval.
- estudante
- trabalhador por conta própria
- trabalhador por conta de outrém
- desempregado
- reformado

5. **Usa smartphone?** *
Marcar apenas uma oval.
- sim
- não

6. **Com que regularidade usa os transportes coletivos?** *
Marcar apenas uma oval.

- raro
- às vezes
- regular

7. **Maioritariamente, opta pelos transportes coletivos para deslocações de...?** *
Marcar apenas uma oval.

- escola/ trabalho
- lazer
- outros

8. **Normalmente, como ocupa o tempo enquanto está à espera do transporte e durante a viagem?** *
Marcar apenas uma oval.

- descansar
- conversar
- ler
- telemóvel
- outros

9. **Maioritariamente, como recebe informação sobre os transportes?** *
Marcar apenas uma oval.

- em papel na paragem/ estação ou panfletos
- ecrãs na paragem/ estação
- computador
- telemóvel
- outros

10. **Usa apps relacionadas com transportes coletivos?** *
Marcar apenas uma oval.

- sim
- não
- não tem SP

11. **Está satisfeito com a informação disponível?**
Marcar apenas uma oval.

- sim
- não
- sem opinião

12. **No futuro, gostaria de usar uma app que facilitasse a sua mobilidade urbana?**
Marcar apenas uma oval.

- Sim
- Não

13. **Imagine que tinha uma app que o(a) conetava ao operador de transporte. Da lista de funcionalidades que lhe vou mostrar, qual é o grau de utilidade de cada uma para si? 0-irrelevante, 1-pouco útil, 2-pode ser útil, 3-útil, 4-fundamental**

Marcar apenas uma oval por linha.

		0	1	2	3	4
13.1	expressar opinião sobre o serviço					
13.2	aceder a horários disponíveis e próximas passagens					
13.3	receber avisos sobre alterações do serviço					
13.4	receber avisos tendo conta as suas viagens habituais					
13.5	efetuar pagamentos e validar viagens					
13.6	planear rotas, saber preço da viagem e duração esperada					
13.7	informação sobre lotação do veículo					
13.8	receber informação extra sobre as proximidades					

14. **Quer sugerir alguma funcionalidade? Qual o seu grau de utilidade?**