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A PARTICIPATIVE SERVICE DESIGN FRAMEWORK FOR URBAN MOBILITY IN A SOCIO-TECHNICAL TRANSITION CONTEXT

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"For I know the plans I have for you,"
declares the Lord, "plans to prosper you
and not to harm you, plans to give you
hope and a future.

Jeremiah 29:11 (Bible NIV)

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ABSTRACT

The increasing complexity of metropolitan areas with a consistent growth of population has raised several challenges regarding urban mobility and logistics. Cities have become complex dynamic systems where multiple stakeholders perform their activities, sharing the same space and resources. Seeking to improve the quality of life of the citizens, municipalities are investing in new solutions for the use of public spaces and the mobility of people and freight. However, the increasing level of digitalization and the multiplicity of information and technology communication tools led us to a socio-technical transition period with visible changes in the behaviour of people and emerging new business models, thus creating even more challenges for urban planning and urban mobility.

Common strategies to tackle these problems are based on designing new policies or improving transportation networks, either by investing in infrastructure or optimizing transport services and operations. Nevertheless, if the ultimate goal is to improve the quality of urban life, those solutions must be centred on the needs of urban stakeholders, mainly the citizens. Moreover, recent European guidelines point towards the integration of different transport modes, creating multimodal networks and the consideration and study of the interactions between land use and urban mobility. The current socio-technical transition period, grounded on the digitalization trends and the awareness of a need for integrated solutions, provided the opportunity to design and deploy a multidisciplinary approach to handle current challenges. Observing cities as complex systems allows us to apply concepts commonly used in service design, such as service-dominant logic and value co-creation, in order to improve the participation of the different stakeholders and include citizen-centred solutions in the design of smart sustainable cities.

One main contribution of this thesis is the multidisciplinary approach designed around four dimensions of the urban context (*social, urban, technological,* and *organizational*). This approach is based on three concepts that result from adopting a service-dominant logic perspective. Considering technological resources for digital communication, we have developed a conceptual framework for integrated information systems with the goal of improving the way stakeholders share and access information and, consequently, enhance their decision-making processes. Finally, the application of the framework in four distinct cases allowed for the development of a set of generic guidelines that can help increase stakeholder participation and engagement. The cases also serve as a validation of the framework, showing its versatility and application potential.

Keywords: urban mobility; urban planning; service design; service-dominant logic; information systems; stakeholder participation; value co-creation.

RESUMO

O aumento da complexidade das áreas metropolitanas, acompanhado do constante aumento de população, tem criado novos desafios para a mobilidade e logística urbanas. As cidades tornaram-se sistemas dinâmicos complexos onde diversos atores realizam as suas atividades, partilhando o mesmo espaço e os mesmos recursos. Procurando melhorar a qualidade de vida dos cidadãos, os municípios têm investido em novas formas de utilizar os espaços públicos, e em novas soluções para mobilidade dos cidadãos. Contudo, a existência de diversas ferramentas de tecnologias de informação e comunicação e o aumento da digitalização, criou um período de transição socio-técnica, levando a mudanças visíveis no comportamento das pessoas, ao mesmo tempo que surgem novos modelos de negócio, aumentando ainda mais os desafios para o planeamento urbano e para a a mobilidade urbana.

As habituais estratégias para abordar estes problemas baseiam-se na criação de novas políticas públicas ou na melhoria das redes de transportes, seja através de investimentos na infraestrutura ou da otimização dos serviços e operações de transportes. Ainda assim, se o principal objetivo é melhorar a qualidade de vida no espaço urbano, essas soluções devem ter como foco as necessidades do atores do meio urbano, principalmente dos cidadãos. Além disso, as recentes orientações da União Europeia apontam para a integração de diferentes meios de transporte, levando à criação de redes multimodais e tendo em conta as interações entre uso do solo e mobilidade urbana. O atual período de transição socio-técnica, potenciado pela digitalização e pela necessidade de soluções integradas, originou a oportunidade de desenhar uma abordagem multidisciplinar para lidar com os desafios atuais. Estudar as cidades como sistemas complexos permite a aplicação de conceitos habitualmente usados no desenho de serviços, tais como lógica serviço-dominante e co-criação de valor, para melhorar a participação de diferentes atores e para incluir soluções focadas nos cidadãos no desenho de cidades inteligentes e sustentáveis.

Uma das principais contribuições desta tese é a abordagem muldisciplinar que considera quatro dimensões do contexto urbano (social, urbana, tecnológica e organizacional). Esta abordagem é baseada em três conceitos que derivam da adoção de uma lógica serviço-dominante. Tendo em conta os recursos tecnológicos que suportam as comunicações digitais, foi desenvolvido uma *framework* para um sistema de informação integrado, com o objetivo melhorar a forma como os atores partilham e acedem a informação, e consequentemente, melhorar os processos de tomada de decisão. Por fim, a aplicação desta *framework* em quatro casos distintos permitiu a criação de um conjunto de linhas orientadoras que permitem melhorar a relação entre os diversos atores. Estes casos também servem como forma de validar a *framework* mostrando a sua versatilidade.

Keywords: mobilidade urbana; planeamento urbano; desenho de serviços, lógica serviço-dominante; sistemas de informação; participação; co-criação de valor.

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ICT – Information and Communication Technology/Technologies

S-D – Service-Dominant

MIS – Management Information System

ERP – Enterprise Resource Planning

MRP – Materials Requirements Planning

MRP II – Manufacturing Resource Planning

CRM – Customer Relationship Management

DSS – Decision Support System

EAF – Enterprise Architecture Framework

EA – Enterprise Architecture

IS – Information System(s)

IS – Information System Architecture

IT – Information technology

BPM – Business Process Map/Mapping

RQ – Research Question

RO – Research Objective

SSC – Smart Sustainable City

AV – Autonomous Vehicles

LUP – Land Use Plan

SUMP – Sustainable Urban Mobility Plan

PMOT – Plano Municipal de Ordenamento de Território (Territory Management Municipal Plans)

PDM – Plano Director Municipal (Municipal Master Plan)

PU – Plano de Urbanização (Urbanization Plan)

PP – Plano de Pormenor (Detailed Plan)

MCDA – Multicriteria Decision Analysis

MGDM – Multicriteria Group Decision-Making

MAMCA – Muti-actor Multi-criteria Analysis

SMCA - Social Multi-criteria Analysis

PEDU – Plano Estratégico de Desenvolvimento Urbano (Strategic Plan for Urban Development)

PARU – Plano de Acção de Regeneração Urbana (Action Plan for Urban Regeneration)

PAICD – Plano de Acção Integrada para Comunidades Desfavorecidas (Integrated Action Plan for Disadvantaged Communities)

LTZ – Limited Traffic Zones

G-D – Goods-Dominant

MSD – Multilevel Service Design

SD4VN – Service Design for Value Networks

CEM – Customer Experience Modelling

SSA – Service System Architecture

SSN – Service System Navigation

SEB – Service Experience Blueprint

EAD – Enterprise Architecture Design

EAP – Enterprise Architecture Planning

TOGAF – The Open Group Architecture Framework

TEAF – Treasury Enterprise Architecture

DoDAF – Department of Defense Architecture Framework

BPMN – Business process modelling notation

FEAF – Federal Enterprise Architecture Framework

SULP – Sustainable Urban Logistics Plan

UTNDP – Urban Transport Network Design Problems

RNDP – Road Network Design Problem

PTNDSP – Public Transit Network Design and Scheduling Problem

STCP – Sociedade de Transportes Coletivos do Porto

CP – Comboios de Portugal (Portuguese Railways)

AMP – Área Metropolitana do Porto

SIA – Sistema Intermodal Andante (Andante Intermodal System)

AFC – Automated Fare Collection

NFC – Near Field Communication

BLE – Bluetooth Low Energy

CBD – Central Business District

SG – System Guidelines

PG – Process Guidelines

1
INTRODUCTION

1.1 CONTEXT AND MOTIVATION

The growth of cities is highly related to transport evolution. For centuries, transport networks were designed to allow the flow of people and goods. Therefore, the urban layout evolved as transport technology changed, leading to different shapes depending on the primary transport mode (Snellen, Borgers, and Timmermans 2002). In the last decades, it became clear that car ownership could not increase forever. It was necessary to find solutions to improve mobility with low negative impacts in the city. One of the main objectives was to increase accessibility by improving urban mobility (Rode et al. 2017).

However, cities are not static and can be considered dynamic systems that change with several factors. Economic cycles and technology usage change citizens' habits and behaviours, creating the need for better transport systems. These changes will attract new population segments, leading to demographic change, which then leads to further changes in the city (Figure 1.1).

New challenges arise as urban population keeps increasing, and negative impacts keep growing. In the EU alone, urban population may reach 80% of the total population by 2050 (ALICE 2015). Statistics show that urban areas are growing, leading to more megacities with larger suburbs (ALICE 2015; The Economist 2014). The increase of the suburban regions leads to the rise of commuters towards the centre (The Economist 2014), hence the importance of choosing the right mobility policies.

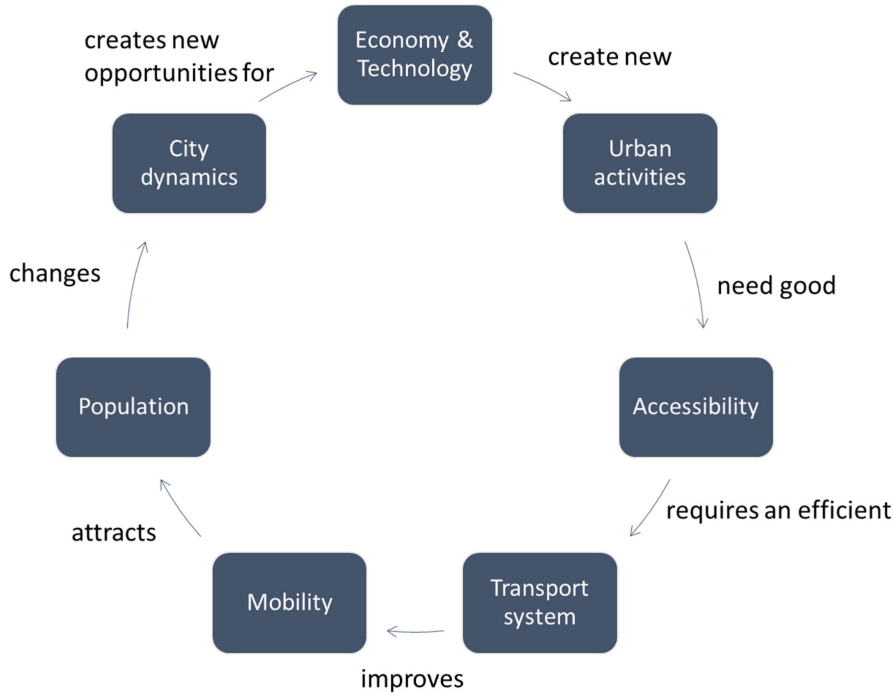

Figure 1.1. Urban system loop.

To decrease the negative impacts of urban growth, local authorities are seeking new solutions to make the city more sustainable. Transportation is especially relevant due to its essential role in citizens' daily lives and its significant environmental impacts. Although other sectors are steadily decreasing emission levels, that is not the case of the transport sector (European Union 2017).

Besides congestion, the increasing number of trips also increases air and noise pollution, reducing the quality of life in urban areas (Fagnant and Kockelman 2015; Cochrane et al. 2017; Lindholm and Behrends 2012). But businesses also suffer the negative impacts of congestion because it delays deliveries and increases shipping expenses (Downs 2004).

Since the efficiency of the urban mobility solutions relies on the efficiency of public transport, freight transport, and the individual usage of the network, there have been significant developments in the design of multimodal networks. Planning for a multimodal network means integrating road and rail, private and public, and even passenger and freight (Sousa and Mendes-Moreira 2015). However, transport planning should consider other characteristics of the city such as morphology, economic activities, and population.

The concern for an integrated approach to urban mobility is also visible in the European guidelines for Sustainable Urban Mobility Plans (SUMP) that envision a global plan for all urban activities (European Commission 2013). SUMP guidelines not only point towards more integration between different transport systems that coexist in the city, but they also stress the need to integrate urban and mobility planning (Rupprecht 2019).

Adding to the existing challenges, recent developments in technology, namely the evolution in information and communication technologies (ICT) and the increasing digitalization level are significantly changing how people behave, interact, and communicate; and how companies provide their services. The deployment of new technologies in developing new transport modes and services will also affect how and why people travel. Despite that, technology usage varies across different age ranges (Alessandrini et al. 2015), and this must be taken into account by urban and mobility planners in order to create more inclusive solutions.

The current period of societal changes caused by technology represents a socio-technical transition during which organizational and institutional changes need to follow technology trends (Spickermann, Grienitz, and Von Der Gracht 2014). In this period, new business models help to bring new technology into the daily activities of cities (Spickermann, Grienitz, and Von Der Gracht 2014). Businesses based on sharing economy principles are emerging. Whether one is paying for car sharing, carpooling, or ridesharing, sharing private transports is becoming more common. This comes with two major benefits: saving time and saving money. In theory, if people share cars, there will be the same number of people in fewer cars, leading to lower congestion levels (Transport & Environment 2017; Glotz-Richter 2016).

Not only passenger-related businesses emerge, but freight-related businesses are changing as well. E-commerce leads to smaller and more frequent door-to-door (D2D) deliveries, increasing the number of urban freight movements. Concepts such as crowd logistics allow common citizens to take part in freight transport (Buldeo Rai et al. 2017), making it more difficult to separate passenger and freight transport. These new socio-technical aspects must, therefore, be included in new action plans. Governments and companies should take advantage of technology to align their policies and regulations with the contemporary urban scene.

The socio-technical transition can be viewed as an argument in favour of improving participation and collaboration in urban and mobility planning. If changes are visible in citizens' behaviour and in both passenger and freight businesses, all stakeholders should participate in urban and mobility planning (Macharis, Turcksin, and Lebeau 2012; Nathanail, Gogas, and Adamos 2016). Not only will their participation improve the end result, but it will also enhance knowledge co-creation by promoting information sharing and transparency (Deligiannidou and Amaxilatis 2016).

Moreover, methods used in service design have proven to be successful in involving different stakeholders, by fostering a co-creation environment and by empowering customers. Hence, adapting some service design concepts to the urban context can assist municipalities in overcoming some of the existing challenges in stakeholders' participation.

In a service exchange, value is co-created through physical or virtual interactions between networks of suppliers and customers (Frow et al. 2014; Patrício et al. 2018). According to the service-dominant (S-D) logic, value is co-created with customers, as they play an active, connected and informed role in the value creation process (Vargo and Lusch 2008).

By considering the three elements of the framework presented by Lusch and Nambisan (2015) – service ecosystems, service platforms, and value co-creation – it is possible to adopt an S-D logic to design an integrated approach to urban and mobility challenges. This perspective is justified when assuming that citizens' well-being must be central in planning activities. Therefore, it is possible to compare cities to services (city as a service), citizens to customers, and municipalities to services providers. The concept of *smart city as a service system* demonstrates the advantages of fostering value co-creation and sharing information in the urban context (Polese et al. 2019).

Moreover, the service design domain has strongly embraced information technologies, allowing for new services to adapt to the digital world (Grenha Teixeira et al. 2017; Lusch and Nambisan 2015; Patrício et al. 2011) and following the trend of digitalization in the socio-technical transition period. Therefore, an S-D logic can help, not only in improving participation but also in facing the digitalization challenges.

However, not every activity of the municipality can be directly compared to a traditional service as provided by a company. Specific characteristics of city management such as budget, organizational structure, bureaucracy, and legal obligations can be barriers to the digitalization success. In these cases, the answer may be viewing the municipality as an enterprise. For that reason, digitalization in this context encompasses resorting to Management Information Systems (MIS). In the case of municipalities, examples of these systems are the Decision Support Systems used in operations planning and management, and Customer Relationship Management software (CRM) used in managing the support to citizens. Even though information systems are already in use by municipalities, they need to be rethought and redesigned to take into account the new socio-technical trends. Hence, in addition to the S-D logic approach, it is necessary to consider information system (IS) design methods such as Enterprise Architecture Frameworks (EAF).

Information Systems (IS) have the potential to solve many of the issues presented here if they explicitly consider multiple perspectives. First, information with varying degrees of detail about aspects such as traffic congestion, service levels, parking, or traffic lights, is essential for urban planners, transportation system users (citizens), logistics service providers, public transportation operators, and others. Having access to relevant information can significantly increase the quality of the decisions made by urban and mobility planners (supply) and citizens (demand). This will positively impact the efficiency of the transportation network. Second, integrating information from different sources increases the knowledge stakeholders have about the city. Thus, IS are essential in generating a co-creation environment where collaboration and participation occur naturally.

In short, studying the city in a socio-technical transition context generates a case for a multidisciplinary approach. Considering the city as an object of study, it is necessary to understand population, their behaviour, and needs. This includes the relationship people have with the territory and how people move in that territory. In a more digital world, this encompasses understanding how technology is shaping people's behaviours and taking advantage of that digitalization to improve the quality of life of the citizens. In the light of this multidisciplinary context, *integration* emerges as a natural solution.

This novel approach to urban and mobility planning seems to add a significant value to existing research due to its focus on an integrated view of multiple problems and its multidisciplinary perspective.

1.2 RESEARCH PROBLEM AND OBJECTIVES

This research was driven by the goal of contributing to a cultural change in the urban context to pursue higher levels of integration, as presented above. When governments are pushing towards more sustainable cities, including more sustainable and efficient urban mobility, we believe that a change is needed in the way urban mobility is approached. Instead of dealing directly with the problems of climate change, transportation planning, or even land use planning, this research deals with those issues indirectly, in a higher and more abstract level, by proposing a new approach to how urban stakeholders interact, how they obtain information and how they influence each other decisions and behaviours.

The main problem addressed in this work can be summarized in one word: *integration*. The systemic approach to cities provides the context for a multidisciplinary approach since it considers, at the same time, socio-demography, technology, mobility, land use, and service management. A second concern that emerges from involving people in decision processes is the development of a participatory and collaborative environment that can only exist in a context where information is easily accessed and shared.

These integration issues can be overcome if there is co-creation of valuable information that can influence decisions and behaviours. In the context of urban mobility, the expected end result of co-creation is the mutual understanding of other users of the transportation system regarding the shared use of space (different modes coexisting in the same network) and the respect for the urban mobility policies.

In the light of the above-mentioned issues, the fundamental goal translates into the following research question (RQ):

> *How to improve information co-creation for urban mobility, in a socio-technical transition context?*

To address this main research question, three main research objectives were outlined:

RO1. To understand urban mobility through a multidisciplinary approach.

RO2. To develop a conceptual framework for redesigning information systems to support urban mobility management and urban planning.

RO3. To develop a set of guidelines to increase stakeholders' participation and collaboration in the urban context.

The way and sequence in which these three objectives were outlined assures that each objective contributes to the next one. The first research objective (RO1) provides the foundation and the adopted positioning regarding urban mobility. Its purpose is to understand how different concepts from other research domains can be adapted to the urban mobility context, thus creating a new integrated perspective of urban mobility issues. Achieving this objective requires exploring a systemic perspective of the city. Moreover, it also demands understanding how different research domains can contribute to improving co-creation in the urban context.

The second objective (RO2) materializes the integrated multidisciplinary approach developed in RO1. It consists of the development of a conceptual framework that takes into account different constructs from different areas (e.g., frameworks, methods, etc.), adapting those constructs to the urban mobility context to represent the integrated vision of the city as a system. Due to the focus given to a socio-technical transition period, the framework resorts to multi-channel information systems to create an inclusive environment where all stakeholders are included.

RO3 emerges naturally from RO2. The framework provides the mind-set to deal with urban mobility planning and management, resulting in guidelines that aim to improve interaction between stakeholders. The framework was then applied to a few illustrative cases.

1.3 Methodological overview

To successfully respond to the objectives presented in the previous section, a combination of methods was selected. The first research objective (RO1) comprises the theoretical framing of the research and was developed based on the information collected in the scientific literature, newspapers and websites, and conferences.

There were two central stages of the literature review. The first stage aimed at understanding the current practices and problems in urban mobility management and planning. Since the research was based in Portugal, Portuguese regulations were studied. The second literature review stage comprised the study of existing methods in other research domains, namely Information Systems and Service Design. This second stage of literature review supported the development of research objectives 1 and 2, providing the theoretical background for developing the multidisciplinary approach and the methods included in the framework.

Following the recommendations proposed for the design of frameworks (Hevner et al. 2004; Peffers et al. 2012), the suitability of the proposed framework was demonstrated through a set of cases represented by illustrative scenarios.

To develop these cases, interviews with experts and practitioners were performed. Those interviews helped in designing the cases as close to reality as possible. Moreover, the interviews supported the identification of best practices, thus fulfilling the third research objective (RO3). The illustrative cases and the resulting guidelines were also used to adjust the framework, in an iterative process.

1.4 Main contributions

This thesis contains three main contributions.

The first major contribution is the multidisciplinary approach to urban planning and urban mobility that results from a vision of the city as a service, and has a strong focus on integration. The proposed approach covers aspects related to changes in technology, in society, in policy design (decision-making), and in urban mobility and urban planning.

This approach can be seen as the starting point to rethink and redesign how information is shared and how people interact, leading to the development of a conceptual framework for the design of an integrated information system. This is the second contribution of this thesis. The framework combines knowledge, methods, and tools from service design and information systems.

Finally, the third main contribution of this work is a set of guidelines for improving value co-creation among stakeholders. These guidelines suggest how the framework can be applied in specific cases.

Together, these contributions help in answering the main research question, in a progressive way along the research development. The multidisciplinary approach provides the vision and logic for how urban mobility should be tackled. Then, the conceptual framework provides the structure to enable the usage of technology-based services to enhance urban mobility. Finally, the guidelines show some aspects to take into consideration when redesigning existing services and systems.

1.5 Thesis outline

This thesis is organized as follows.

Chapter 2 provides a literature review on urban mobility and urban planning, including some considerations about the relationship between transport evolution and the urban space, and the evolution of concepts linking technology and cities (e.g., smart city). To completely understand the challenges and requirements of the urban mobility context, this chapter includes a description of Portuguese regulation and the identification of transportation problems. This chapter finishes with a description of the research opportunity to be addressed by this work.

Chapter 3 is a literature review setting the theoretical background for the work developed in the following chapters. It describes the existing methods and tools from the research domains that are part of the multidisciplinary approach and the conceptual framework, namely Information Systems and Enterprise Architecture Frameworks and Service Design. The chapter also presents existing theoretical works in public participation.

Chapter 4 describes two of the main contributions of this thesis. First, we present the multidisciplinary approach, that results from the literature review in chapter 2. Then, we describe the conceptual framework, that emerged from the multidisciplinary approach and uses methods presented in chapter 3. This chapter fulfils RO1 and RO2.

Chapter 5 describes the four illustrative cases that exemplify the application of the multidisciplinary approach and validate the framework. For each case, we establish a relation between the framework and the methods used and propose the redesign of one or more processes. Each case highlights a facet of the framework.

Chapter 6 continues the work begun in chapter 5. It presents the main findings from the four illustrative cases and the resulting guidelines, thus fulfilling RO3. Then, considering the guidelines and the structure presented in chapter 4, we refine the framework and draw some practical considerations for the development of an information system.

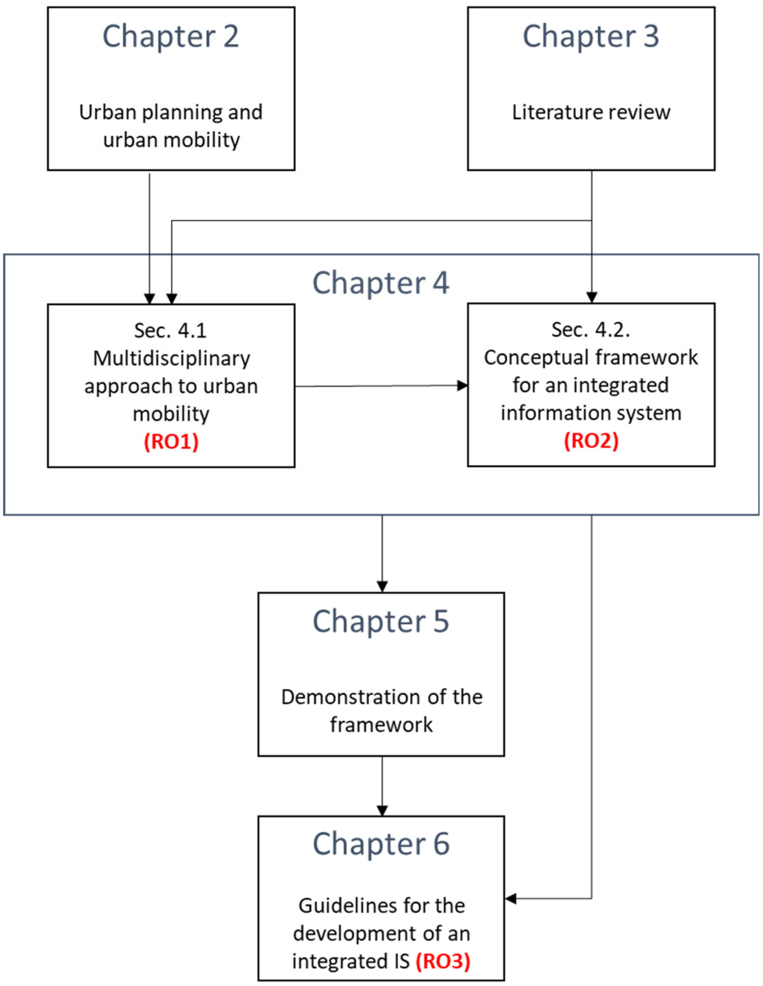

Figure 1.2. Thesis outline overview

Due to the iterative process of the research methodology, chapter 6 somehow complements chapter 4. However, the illustrative cases described in chapter 5 contribute to the guidelines and the refinements of the framework, and therefore we have opted to separate the three chapters.

Chapter 7 concludes this thesis by revisiting the research objectives and discussing the main contributions of the research. It also provides some future research directions.

Figure 1.2 shows how the thesis is organized, with the relations between chapters, and their links to the research objectives.

2

URBAN PLANNING AND URBAN MOBILITY

This chapter starts with a brief reference to some concepts that are important to the research. Then, considerations are made about the evolution of transportation and urban space. In the end, current regulations and common transport network problems are presented. This overview on different topics related to urban mobility allowed us to identify the gaps in the literature, that justify our research.

2.1 CONCEPTS

Before presenting the literature review, it is important to clarify some underlying concepts. Currently, cities are seeking to increase sustainability and implement new technologies. Moreover, mobility plans are used to plan transport networks and services to improve urban mobility. Hence, the concepts of smart sustainable city (SSC) and urban mobility are addressed here.

2.1.1 SMART SUSTAINABLE CITY

The current research in urban planning or transport topics often refers to the concepts of urban sustainability or sustainable cities. Though the concepts have first appeared related to pollution control in 1986, they have evolved to include the technological reality of the 21st century. It is common to see the concept of sustainability related, not only to environmental issues but also to economic issues in the city. Then, with the evolution of technology, the concept of smart city started to emerge. This means that now, the concepts of sustainable city and smart city are highly connected. Even if the concept of smart city is more associated with technology usage, urban sustainability also relies on technological innovation (Fu and Zhang 2017). Other concepts that relate to the socio-eco-economic triangle may refer to only one aspect of the urban system, as it is the case of eco-city, low-carbon city, green city, digital city, liveable city, information city, or knowledge city (Fu and Zhang 2017; Jabareen 2006; De Jong et al. 2015).

In this context, one can say that a sustainable city is a city that promotes energy and mobility efficiency, meaning that citizens can easily perform their business and leisure activities with low energy consumption but with high economic and personal gains. When compared to the concept of sustainable cities, smart cities emphasize the use of technology to improve socio-economic activities and do not include the environmental aspects of the city (Fu and Zhang 2017). As technology usage grows, the concept of smart city is also gaining attention, but the frameworks related to smart cities lack environmental concerns. Since the goal is to improve sustainability through technology, some authors argue that environment should not be neglected and refer to the concept of *smart sustainable cities* (Ahvenniemi et al. 2017; Bibri and Krogstie 2017).

Since the previously mentioned concepts only focus on one of the aspects of sustainability (eco-city, green-city, etc.) we believe that the *smart sustainable city* is, in fact, the concept that better describes the goal for the cities of the 21st century.

2.1.1 Urban Mobility and Accessibility

Urban mobility is a result of the flow of people and goods in the urban area. It derives from the interaction of several subsystems that coexist in cities (Nemtanu et al. 2016; Fistola and Raimondo 2017), and new approaches to mobility have therefore to consider the relationships between how, why and where people and goods move:

- *How,* relates to the transport services that carry passengers or freight.
- *Why*, refers to the activities performed by citizens.
- *Where,* means the infrastructure and the transport networks used.

Mobility is defined as "*the ability to move or be moved freely and easily*" ("Oxford Living Dictionaries" n.d.). Therefore, improving urban mobility is improving people's ability to move inside the city. When one thinks about improving mobility, it is common to think about the efficiency of the transportation network (time, pollution, and other quantifiable factors). However, improving the perception of the quality of mobility is equally an important aspect to be considered.

Another key concept that relates to urban mobility is accessibility. In an urban environment, this idea focuses on the ability to access places. Accessibility is the result of good urban planning and efficient transport systems (Chen et al. 2018; Rode et al. 2017). Increasing people's ability to easily move (*mobility*) will increase their access to activities (*accessibility*), with significant economic benefits for the society (Li and Liu 2017).

The relationship between mobility and accessibility strengthens the dependency between transportation and land use.

2.2 URBAN SPACE AND TRANSPORTATION EVOLUTION

The evolution of urban mobility patterns was mainly caused by the increasing capabilities of transportation and consequently has influenced changes in the development of the urban space. The fastest the transport, the longer the distance a person could travel and the larger the city would become.

Using the city of Porto as an example, we can see that 100 years ago the city was contained in what today is considered the "downtown" (Figure 2.1), and what was the suburbs is now part of the city. In fact, the houses near the ocean (in today's Foz do Douro borough) were mainly for weekends and vacation of wealthy people (Duarte 2009).

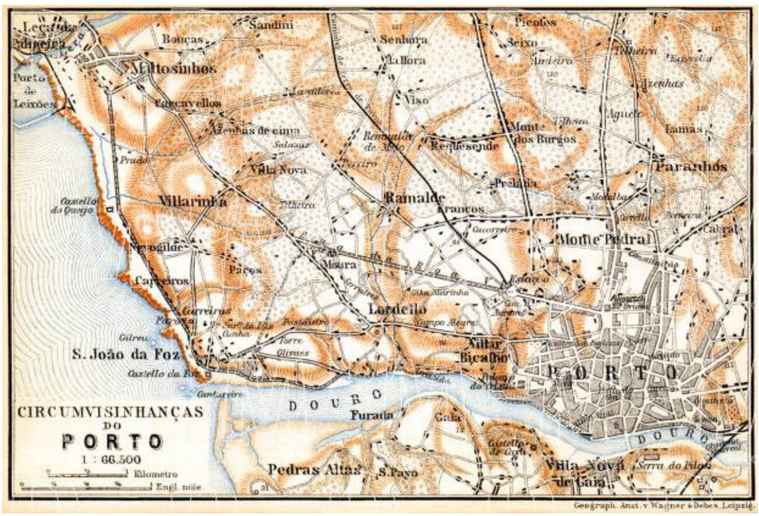

Figure 2.1. Porto, 1900 (https://www.discusmedia.com/maps/porto_city_maps/3792, accessed 29th April 2021)

While public transport networks emerged during the 1800s with the use of horse buses, urban spaces started to change with the deployment of the first railways during the 19th century, with the oldest underground line in London – the Metropolitan Railway opened in

1863 (“London Transport Museum” n.d.), and after, in the 1880s, in Germany with the first electric tram line (Siemens n.d.). But it was in the 20th century that the car revolutionized the way people could move freely, with the mass production of the Ford T in 1908.

Today, urban areas continue to attract more people (Figure 2.2) and suburbs continue to grow (*The Economist* 2014).

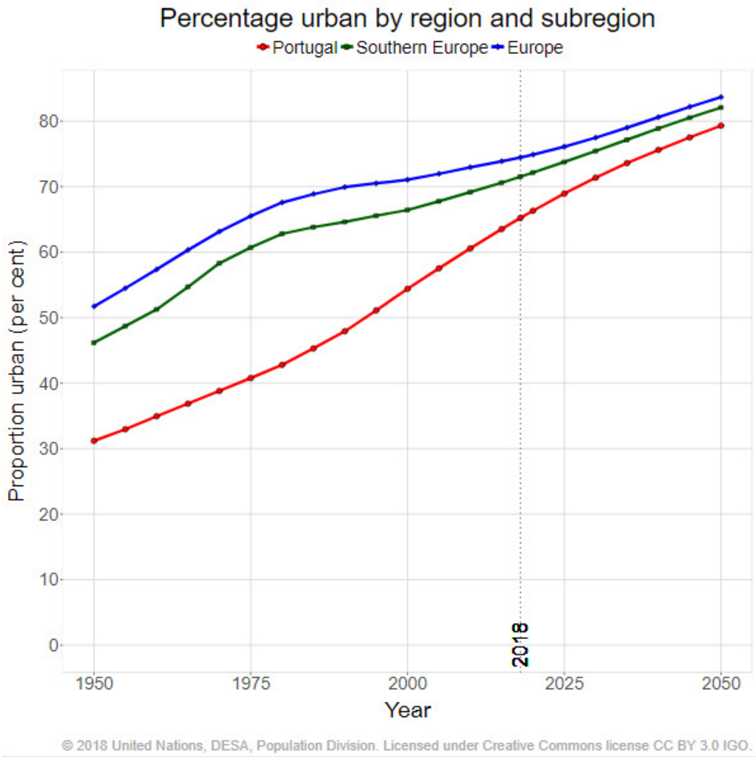

Figure 2.2. Evolution of urban population, United Nations (https://population.un.org/wup/Country-Profiles/).

Still, the same car-dependent urban lifestyle has been growing in developed countries. Data shows that, in 2015, there were 498 cars per 1000 inhabitants in the EU-28 (European Union 2017). This evolution is increasing congestion and pollution, and strongly decreasing the quality of life in large urban areas. Concerns about environmental issues in the urban space have drawn attention to a need to change transportation since, while most sectors have been decreasing emissions, that is not the case of transportation that is responsible for one-third of total emissions, and still increasing (European Union 2017, Figure 2.3).

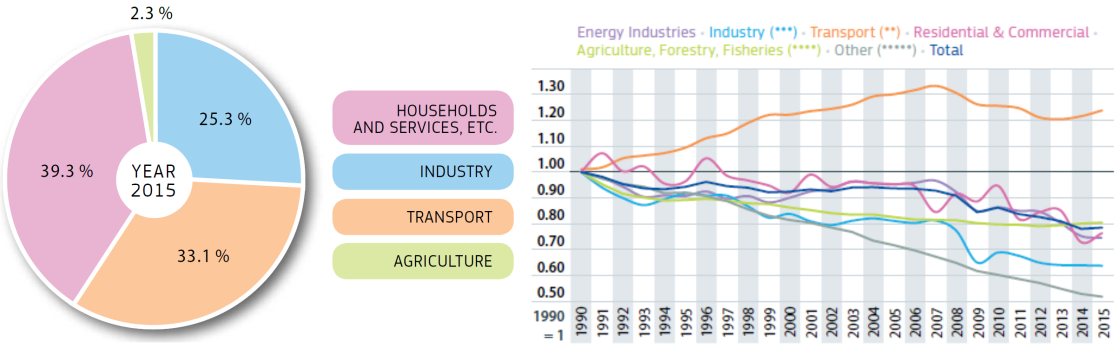

Figure 2.3. Energy consumption per sector, in Portugal, in 2015 (European Union 2017).

For years, several solutions have been experimented in cities everywhere in the world. Some cities developed attractive public transports, increased sidewalks, and reduced street capacity, as strategies to reduce the use of private transportation. Other cities tried to discourage the usage of more congested roads by implementing taxes where congestion was higher; or even by implementing taxes to enter the city. Some initiatives were successful for a while, but cities continue to grow, and people still depend on urban areas to get access to public services, retail, workplaces, etc.

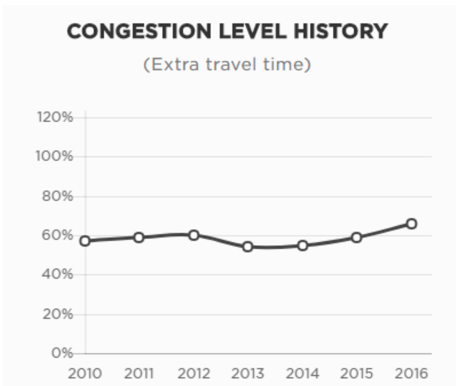

Figure 2.4. Congestion levels for Mexico City ("Tomtom Traffic Index" 2017).

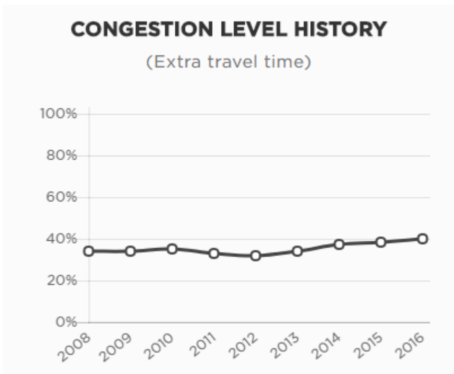

Figure 2.5. Congestion levels for London ("Tomtom Traffic Index" 2017)

Mega-cities in developing countries are those facing major problems. In 2017[(1)], Mexico City was at the top of the congestion ranking, with a congestion level of 101% in the evening peak ("Tomtom Traffic Index" 2017) and an extra travel time increasing tendency (Figure 2.4).

[(1)] We chose to ignore data from 2020 since, due to the covid-19 pandemic, it does not fairly represent the reality of transportation.

Even first-world countries, that have been dealing with the problem for decades, are still far from finding a solution. For instance, London had a congestion level of 40% with a peak of around 70% (Figure 2.5). Despite being much lower than Mexico City, it also shows the same growth trend, being 25th on the ranking.

As public policies have been unable to successfully address the problem, *sharing economy* started to make progress in transportation systems. Uber is probably the most known example, although there are several other cases based on the same principles. Whether one is paying for car sharing, carpooling, or ridesharing, sharing private transport vehicles is becoming more common. In theory, if people share cars, there will be the same amount of people in less cars, which will lead to lower congestion levels.

The car is still the preferred vehicle, representing up to almost 70% of modal share in Portuguese larger cities (INE - Instituto Nacional de Estatística 2018). In fact, the car industry is still pushing to innovate private and individual vehicles, only considering the problems of emissions and not the problem of the occupied space. In fact, there is a regulation regarding carbon emissions for motorized vehicles, but there is no regulation for other technologies or components that have been turning cars into more than just vehicles, but symbols of economic status (Pojani, Van Acker, and Pojani 2018). For instance, the design of car lights is part of a broader marketing strategy that goes far behind the normal lightning requirements.

One of the solutions proposed by the car industry to change mobility are the *autonomous vehicles* (AV) that are expected to serve people's goals with a decrease in time, pollution, traffic, and accidents. Still, there are some uncertainties regarding the true impact AV may have in cities (Alessandrini et al. 2015; Fagnant and Kockelman 2015; Hörl, Ciari, and Axhausen 2016; Pillath 2016). Promises include improvement in urban traffic and congestion, lower pollution levels, and increased mobility and safety due to less human caused-accidents (Hayes 2011; Moore and Lu 2011; Fagnant and Kockelman 2015). On the other hand, successful examples of autonomous public transport start to emerge with promises of a less congested city (e.g., London).

At the same time, in another line of research promoted by urban planners, are the soft or active modes, and better usage of public space (Southworth 2005; Moura, Cambra, and Gonçalves 2017; Bhattacharyya and Mitra 2013). Moreover, some promote the concept of *compact city* as a new way of living, increasing proximity and reducing travelling (Varma 2017).

The idea of a compact city is disruptive when compared with just improving public transport or private car usage. Instead of promoting and improving movements of people, a compact city invests in people moving less and having everything they need in proximity.

In fact, in the last decade, many European cities have tackled the issue of lowering emissions in the central neighbourhoods by reducing car access (e.g., Ghent, in Belgium, or Pontevedra, in Spain). In 2019, Barcelona presented a plan for creating superblocks (groups of 9 blocks) where cars have no access, and that will free up to 92% of public space ("Energy Cities" 2019). However, these ideas still promote traveling and require investment in public transport.

At the beginning of 2020, the mayor of Paris, Anne Hidalgo, announced her goal of creating the 15-minute city (Reid 2020), showing the intention of not only improving mobility but the overall accessibility to all services and essential commerce. After a few months, the covid-19 pandemic accelerated the deployment of new solutions across Europe to "give the cities back to people". This sentence has an unknown author and was used by many to show the new emerging paradigm.

Cities such as London and Milan strongly invested in the creation of cycle networks to foster the usage of bicycles. Meanwhile, in the USA, social media users were sharing how they were taking over the streets, in a broader movement supported by urban planners such as Brent Toderian and Mike Lydon, who are active voices in pushing cities to open streets for people by closing them to cars.

All these examples stress how mobility and land use influence each other and how new social habits are changing the city. Problems often arise when municipalities are not able to keep up with the changes, that strongly depend on the local cultural values. In European countries such as Portugal, it is difficult for a municipality to implement any change without a formal regulation, and changes tend to be more permanent. On the other hand, the "open streets" movement in the USA showed the potential of tactical urbanism, with low regulation and by testing in practice the acceptance of certain measures. This type of experiments clearly facilitates the policy design process, as urban planners know *a-priori* the potential success of a given policy.

2.3 URBAN PLANNING – PORTUGUESE POLICIES

In order to understand the perspective of urban planners, we describe, in this section, some of the current regulations and policy practices in Europe, with a focus on Portugal.

Local authorities and governments recur to regulations to implement strategic plans. Land Use Plans (LUP) or Master Plans are used to determine what types of constructions and activities are allowed in some zones of the city, defining the strategic guidelines regarding land use. The most common types of land use zones are residential, commerce, business, and industrial (Rodrigue 2017). In Portugal, municipalities have Planos Municipais de Ordenamento do Território (PMOT) – Territory Management Municipal Plans – to regulate the possible construction and activity development, depending on the city zone. Since there are different levels of detail, these plans are divided into three groups (IMTT 2011):

- Plano Director Municipal – PDM (Municipal Master Plan) – describing the possible land use in the urban perimeter;
- Plano de Urbanização – PU (Urbanization Plan) – detailing the master plan in a zone of the city;
- Plano de Pormenor – PP (Detailed Plan) – detailing the plan for a specific neighbourhood.

Recently, the EU introduced the concept of Sustainable Urban Mobility Plans (SUMP) so that mobility and transports could be included in the urban planning process. These plans are part of the Mobility Package, and they promote cooperation, bringing together different administrative sectors and different stakeholders. The mobility package was created in 2013 and promotes the development of urban mobility actions for sustainability planning, public transport, urban logistics, and environmental initiatives (green zones and alternative fuels) (European Commission n.d.). In 2019, these guidelines were presented in an updated version which included a 12 step approach structured into four phases (Rupprecht 2019).

According to the Commission's platform for Urban Mobility (ELTIS 2015), a SUMP is a "*strategic plan designed to satisfy the mobility needs of people and businesses in cities and their surroundings for a better quality of life. It builds on existing planning practices and takes due consideration of integration, participation, and evaluation principles*." The Commission also provides some principles and objectives that cities should follow when implementing a SUMP. It is important to highlight that SUMP assume that all modes are developed in a balanced and integrated approach. Therefore, the following topics should be considered (European Commission 2013):

- public transport;
- non-motorised transport;
- inter-modality;
- urban road safety;
- road transport;
- urban logistics;
- mobility management;
- intelligent transport systems.

In the Portuguese case, SUMP were included in a more global plan – the Strategic Plan for Urban Development (Plano Estratégico de Desenvolvimento Urbano – PEDU). Besides SUMP, the PEDU includes the Action Plan for Urban Regeneration (Plano de Acção de Regeneração Urbana – PARU) and Integrated Action Plan for Disadvantaged Communities (Plano de Acção Integrada para Comunidades Desfavorecidas – PAICD) (Specific Regulation for POSEUR - Portaria n.o 57-B/2015, 27th February 2015).

Even though EU guidelines about SUMP are quite recent, congestion and mobility issues have been addressed before. Studies about congestion control usually propose the development of policy measures that discourage private car usage and promote public transport services. In addition, due to its characteristics, freight transport is also regulated. Regulations reflect policy measures used to create Limited Traffic Zones – LTZ (Gholami and Tian 2016; Stathopoulos, Valeri, and Marcucci 2012; Migliore, Burgio, and Di Giovanna 2014). Common practices typically cover the following aspects:

- pricing;
- vehicle weight;
- pollution;
- time windows;
- traveller type (residents, visitors, workers, customers, etc.);
- number of vehicles;
- parking (availability, pricing, location).

Besides LTZ, other measures aim at reducing vehicle circulation inside the urban area. These measures may include capacity reduction, such as *road diet* that reduces car accessibility, by decreasing the number of available lanes for private cars (Gholami and Tian 2016). Table 2.1 gathers these measures into three main groups.

Table 2.1. Traffic reduction policy measures (based on Gholami and Tian 2016)

Policy approach	Examples of measures
Capacity management	Road diet Improved sidewalks
Pricing	Access fee Parking pricing
Restricted access	Vehicle weight Fuel type and emissions Traveller type Time windows

2.4 URBAN TRANSPORT PLANNING

In this section, we briefly address urban transport planning in what concerns the transportation networks design and optimization. Problems related to urban transport planning were first formulated in the 1960s, particularly addressing decision-making processes with limited resources and fulfilling more than one objective (Tong, Zhou, and Miller 2015). These problems may relate to infrastructure or service planning, or to freight or passenger, but they all seek to support a diversity of strategic, tactical, and operational decisions. Common objectives vary throughout time, with a recent focus on accessibility and environmental problems (Tong, Zhou, and Miller 2015; Farahani et al. 2013).

Table 2.2. Urban Transport Network Design Problems and Sub-problems (based on Farahani et al. 2013; Cantarella and Vitetta 2006)

<table>
<tr><th colspan="3">Problems</th><th>Decisions</th></tr>
<tr><td rowspan="8">Urban Transport Network Design Problems</td><td rowspan="3">Road Network Design Problems</td><td>Discrete Network Design Problem
(or simply Network Design Problem)</td><td>Constructing roads
Adding lanes
One-way vs. two-way streets and their direction</td></tr>
<tr><td>Continuous Network Design Problem
(or Traffic Signal) Setting</td><td>Capacity
Traffic lights scheduling
Tolls</td></tr>
<tr><td>Mixed Network Design Problem</td><td>Combination of discrete and continuous decisions</td></tr>
<tr><td rowspan="5">Public Transit Network Design and Scheduling Problems</td><td>Transit Network Design Problem</td><td>Routes</td></tr>
<tr><td>Transit Network Design and Frequency Setting Problem</td><td>Routes + Bus frequency</td></tr>
<tr><td>Transit Network Frequencies Setting Problem</td><td>Frequency for a given route</td></tr>
<tr><td>Transit Network Timetabling Problem</td><td>Timetable for a given frequency and route</td></tr>
<tr><td>Transit Network Scheduling Problem</td><td>Frequency and timetable for a given route</td></tr>
</table>

Tong, Zhou, and Miller (2015) identify the work of Magnanti and Wong (1984) as one of the first reviews of network design models and mention the work of Crainic (2000) as a more recent review of freight transport design problems. Farahani et al. (2013) also present a comprehensive review of Urban Transport Network Design Problems (UTNDP) at the date. UTNDP includes the Road Network Design Problem (RNDP) and the Public Transit Network Design and Scheduling Problem (PTNDSP). The RNDP focuses on infrastructure and the PTNDSP on service. These problems can be classified in the sub-problems presented in Table 2.2 (Farahani et al. 2013; Cantarella and Vitetta 2006). Table 2.3 summarizes freight-related issues that are analysed under the Service Network Design Problems presented by Crainic (2000).

Table 2.3. Service Network Design Problems (Crainic 2000)

Problems	Decisions
Service selection	Routes, frequency, and schedule
Traffic distribution	Routes (terminals passed through)
Terminal policies	For each terminal, the consolidation activities
General empty balancing strategies	Empty vehicles repositioning
Facility location*	Location

* may refer to delivery collection kiosks, urban consolidation centres, and others.

2.5 RESEARCH OPPORTUNITY

In this chapter, we discussed how the evolution of transportation systems is linked to the evolution of the urban space. Our literature review shows that researchers and practitioners are both concerned with improving urban quality of life, mostly by focusing on environmental issues. As described, some common approaches to these issues are regulation and policy design or design and optimization of the transport network.

Nevertheless, we live in a socio-technical transition context, with people constantly changing their habits, and with companies developing new business models (see chapter 1). Although cities are creating new regulations or improving infrastructure for optimizing the public transport network, when solutions are implemented, behaviours have already changed, probably jeopardizing the impacts of those solutions.

Hence, there is a need for a new approach that does not focus exclusively on urban planning or on urban mobility but considers the behaviour of those who use the transportation system and the urban space – the citizens. Influencing citizens’ and other stakeholders’ behaviour and decisions will improve the utilization of these assets and resources.

Research on service design and management has shown the potential for improving the results when customers participate and become the focus of the service provider. Service design considers that managing expectations, and really focusing on the needs of the stakeholders, can improve the perception of the system. In the urban context, this can be illustrated by shifting from “I want to go to store A”, to “I need to buy product X, wherever I can find it”. Therefore, urban planners should try to understand what people really need and not where people want to go. In the end, all those decisions require information, and we can take advantage of the increasing level of digitalization in this socio-technical transition context to improve how people interact and access information.

To accomplish this goal, we need to create an approach that resorts to service design concepts and information system tools, adapting them to the urban context. This new approach is described in chapter 4, but before, chapter 3 explores some of the existing methods and tools that support the design that approach.

3

LITERATURE REVIEW

This chapter presents the theoretical background that supports the core of this work. Considering the research opportunity presented in chapter 2, we have studied existing theories that can be adapted to the context of urban mobility in a socio-technical transition period. We first analyse existing methods and procedures for public participation; then, we consider concepts and methods from service design; and, finally, we describe existing frameworks and methods for enterprise architectures and information systems architectures.

3.1 PUBLIC PARTICIPATION AND STAKEHOLDER INVOLVEMENT

Urban activities affect different groups of stakeholders that need to be included in city planning. Lindenau and Böhler-Baedeker (2014) mention stakeholder involvement as a precondition for sustainable mobility. There are at least five main benefits from public participation: increasing process transparency, knowledge base, mutual understanding among stakeholders, acceptability, and considering everyday knowledge (Lindenau and Böhler-Baedeker 2014).

Different European research projects, as mentioned in the roadmap developed by the ERTRAC and ALICE technological platforms for urban freight (ALICE 2015), show that stakeholders' involvement is desired even for urban logistics (BESTFACT 2014; Andersen 2017). Stakeholders may help by bringing to consideration different perspectives, goals, and constraints (Awasthi, Adetiloye, and Crainic 2016; Andersen 2017; Lindawati et al.

2014; Lindholm and Browne 2013). On the other hand, the level of acceptance and open-mindedness may hinder the process (Selhofer, Mahieu, and Gaboardi 2012; Lindawati et al. 2014).

Freight-related studies have also shown that stakeholders should be involved in initiatives related to policy development and technology deployment (Lindawati et al. 2014; Eidhammer, Andersen, and Johansen 2016; Awasthi, Adetiloye, and Crainic 2016). In these two groups of initiatives, stakeholders may participate with different roles and with a different level of engagement. Some authors even classify some initiatives as company driven (Quak and Tavasszy 2011; Macharis and Melo 2011), showing that not all projects are promoted by local authorities.

3.1.1 CONCEPTS

The terms *integration* and *involvement* may be used in similar circumstances since both are related to inclusion. In the literature, different words may refer to stakeholders' involvement in developing an integrated planning strategy, such as participation, collaboration, cooperation, engagement, and integration (Lindholm and Browne 2013; Lagorio and Golini 2016; Kin et al. 2017; Lindawati et al. 2014; Eidhammer, Andersen, and Johansen 2016; Baumann and White 2015; Finka et al. 2017). These concepts focus on different perspectives of policy design, but they all mean that stakeholders' opinions and wishes are included in the process. While collaboration and participation are often considered during the project phase, cooperation implies that stakeholders not only participate in the project but also share some tasks after implementation (Nathanail, Gogas, and Adamos 2016). Regarding participation and collaboration, they may appear in similar contexts, though they might reflect different levels of stakeholder involvement (Soria-Lara and Banister 2017; Baumann and White 2015).

3.1.2 METHODS AND PROCEDURES FOR STAKEHOLDER INVOLVEMENT

Different approaches to urban planning issues reflect various levels of engagement, and the reviewed literature shows diverse levels of interaction among the different stakeholders (Finka et al. 2017; Lindenau and Böhler-Baedeker 2014).

Finka et al. (2017) propose a procedure to engage stakeholders that consists of five phases (Table 3.1) where the level of participation increases from passive to active, from listening to aiding in decision making.

Table 3.1. Participation procedure tools (based on Finka et al. 2017).

Phases	Collaborative behaviour	Tools
0	Stakeholder mapping	Expert opinions, focus groups, interviews, self-selection, public events, check-list of the likely stakeholder categories, etc.
1	Spread of information	Newsletters, advertising in newspapers and on project websites, fact sheets, etc.
2	Collection of information	Pools, surveys, community profiles, briefings, written responses, and online tools, etc.
3	Intermediate discussion	Public meetings, workshops, urban walks, open houses, and any other formats of discussion.
4	Engagement	Negotiations, arbitration, and mediation.
5	Partnership, empowerment	Multi-actor decision-making, voting, or referenda.

By using a structured procedure, it is possible to foster stakeholders' participation, thus increasing their willingness to be involved in the project (phase 1 – spread of information) until they become partners seeking mutual goals (phase 5 – partnership).

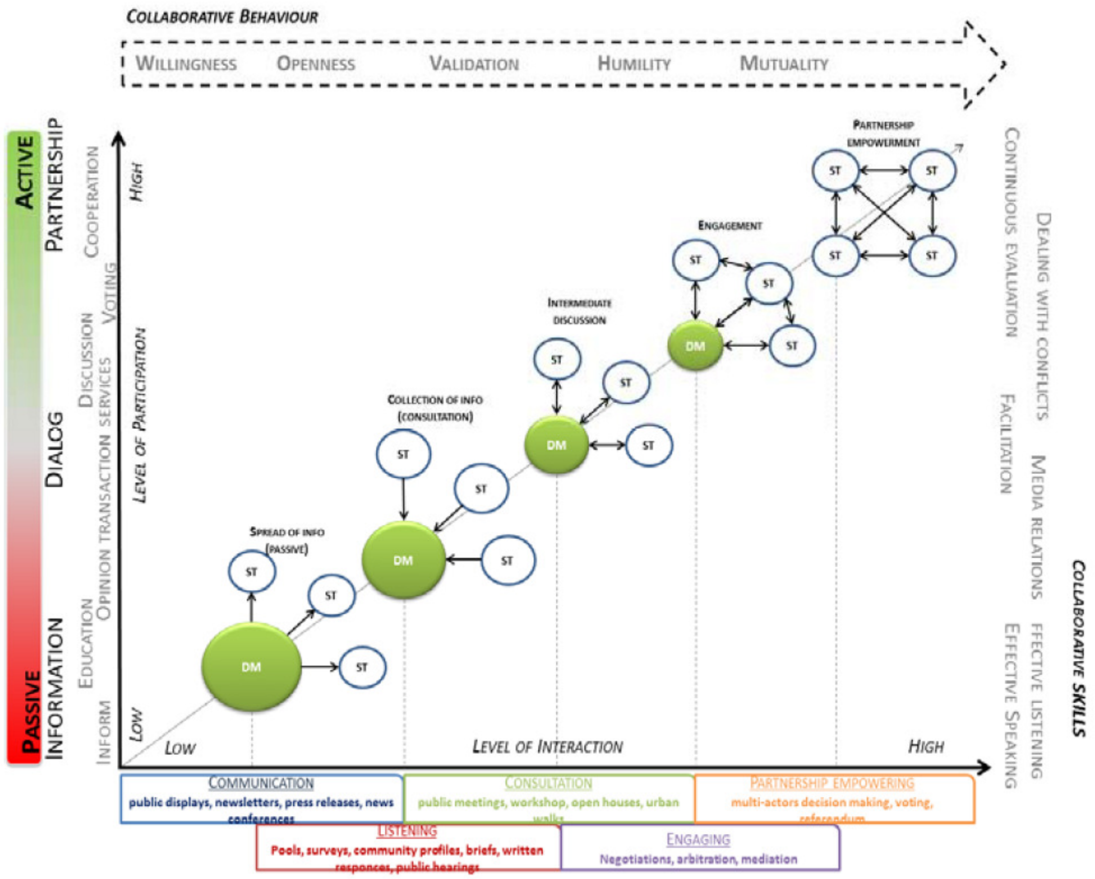

Figure 3.1. Participation procedure (Finka et al. 2017).

In between, stakeholders engagement is done by collecting information in a consultation scenario (phase 2 – collection of information), by discussions using dialogue techniques, and negotiation (phases 3 – intermediate discussion and 4 – engagement) (Finka et al. 2017). This procedure helps to understand the possible existing levels of involvement in transport projects. Figure 3.1 represents the relation between these phases and the level of participation.

Arnstein (1969) presents eight levels of participation, including scenarios of nonparticipation (Figure 3.2).

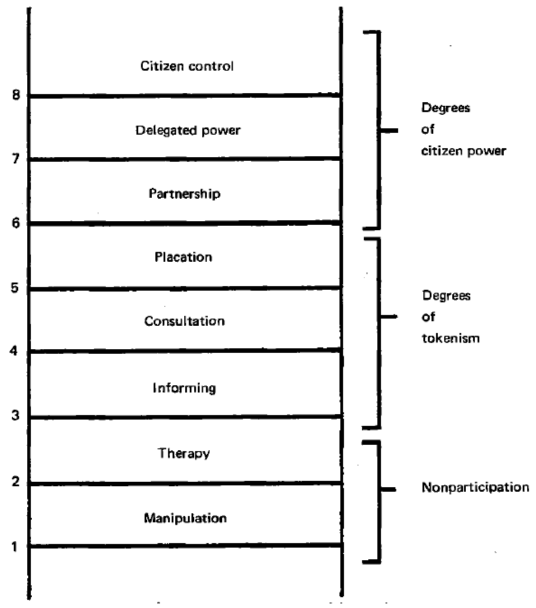

Figure 3.2. Participation ladder (Arnstein 1969)

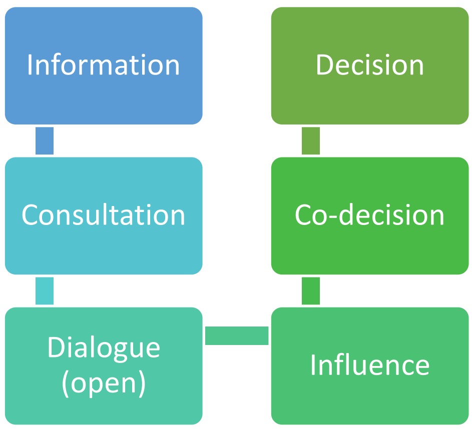

Figure 3.3. Chances and potential of participation for better transport planning presented by Sturm (2013) (based on Lindenau and Böhler-Baedeker 2014)

According to Lindenau and Böhler-Baedeker (2014), Sturm's work refers only six levels of participation, considering *information* to be the most passive form of participation, and *decision* the most active (Figure 3.3). Sturm's six levels of participation are directly related to the six highest levels presented by Arnstein (1969) (Table 3.2).

Table 3.2. Participation levels comparison (Lindenau and Böhler-Baedeker 2014)

<table>
<tr><th>Citizen participation ladder (Arnstein)</th><th>Potential for participation (Sturm)</th></tr>
<tr><td>Manipulation</td><td>-</td></tr>
<tr><td>Therapy</td><td>-</td></tr>
<tr><td>Informing</td><td>Information</td></tr>
<tr><td>Consultation</td><td>Consultation</td></tr>
<tr><td>Placation</td><td>Dialogue</td></tr>
<tr><td rowspan="2">Partnership</td><td>Influence</td></tr>
<tr><td>Co-decision</td></tr>
<tr><td>Delegated Power</td><td rowspan="2">Decision</td></tr>
<tr><td>Citizen Control</td></tr>
</table>

Considering the importance of stakeholder engagement in policy design, the CIVITAS initiative created a toolkit for stakeholder involvement (Civitas 2011). The toolkit report discusses the importance of stakeholder consultation (Table 3.3) and presents five key recommendations for successful involvement: (1) follow the six-step strategy (see below); (2) build effective partnerships; (3) develop a strategy; (4) plan involvement activities; and (5) evaluate and follow-up.

The recommended six-step strategy includes (for more detail see Civitas (2011)):

1. specify the issues to be addressed;
2. identify which stakeholders to involve;
3. analyse the potential contributions of various stakeholders;
4. set up an involvement strategy;
5. consult your stakeholders;
6. evaluate and follow up.

Table 3.3. Benefits of stakeholder involvement (Civitas 2011).

1	Greater stakeholder input improves the quality of decisions.
2	Controversial issues and difficulties can be identified before making a decision.
3	By bringing together different stakeholders with different opinions, an agreement can be reached together. This prevents opposition from emerging later, which can slow down the decision-making process.
4	Stakeholder involvement prevents delays and reduces costs in the implementation phase.
5	Stakeholders gain a better understanding of the objectives of decisions and the issues surrounding them.
6	Stakeholder consultation creates a sense of ownership of decisions and measures, and improves their acceptance.
7	The decision-making process becomes more democratic, giving citizens and local communities the power to influence decisions, and thus a greater sense of responsibility.
8	Stakeholder consultation can help build local capacity.
9	Public confidence in decision makers is enhanced.
10	Stakeholders and decision makers learn from each other by exchanging information and experiences

From the recommendations presented, we focus on a few aspects of our context.

In what concerns *building effective partnerships*, the toolkit refers to the importance of identifying and communicating with the stakeholders to analyse their objectives, and the need to develop a *"planning culture based on a regular communication, mutual consultation, and cooperative decision-making"*. Creating this *planning culture* demands a high level of involvement of all stakeholders in a collaborative and reliable environment, where conflicts can be resolved and do not create more barriers. Only such an environment will foster a good sense of partnership in the stakeholders.

Regarding the *development of a strategy*, the toolkit highlights again the importance of planning by having a well-defined timeline and a budget. That timeline must include the participation of all stakeholders in every stage of the process. Communication between the stakeholders must be transparent in order to avoid negative perceptions, and to enable a well-informed participation of the stakeholders.

To plan successful involvement activities, the toolkit suggests that each activity must consider the level of engagement desired for each stakeholder. Then, the planned activities must include a combination of methods and techniques to reach that level of engagement. Whatever that level is, stakeholder involvement should be present in every stage.

3.1.3 Participation in Decision-Making Processes

The participation of stakeholders has been a concern of research on the decision-making domain, mainly within the Multicriteria Group Decision-Making methods (MGDM), applied in contexts where there are conflicting goals and the decision is not dependent on one single stakeholder (de Almeida et al. 2015). In this section, we briefly present the Muti-actor Multi-criteria Analysis method (MAMCA), which was developed to be applied in the context of urban logistics. MAMCA is an extension of classical MCDA methods that can be used as a method to evaluate policies and help in policy design and decision making for transport-related projects, having the advantage of including stakeholders in a very early stage of the process (Verlinde and Macharis 2016; Macharis, De Witte, and Ampe 2009).

MAMCA is one type of Social Multi-criteria Analysis (SMCA). The motivation for its development came from the fact that, in the context of transport planning, the group is not homogenous. Thus, there should be one value tree per stakeholder (Macharis, Turcksin, and Lebeau 2012). MAMCA was first presented in 2005 (Figure 3.4) and has been used by its authors in several case studies. It has been referred to as a methodology, a framework, and a method (Macharis 2005; Macharis, De Witte, and Ampe 2009; Macharis, Turcksin, and Lebeau 2012; Macharis et al. 2014; Kin et al. 2017).

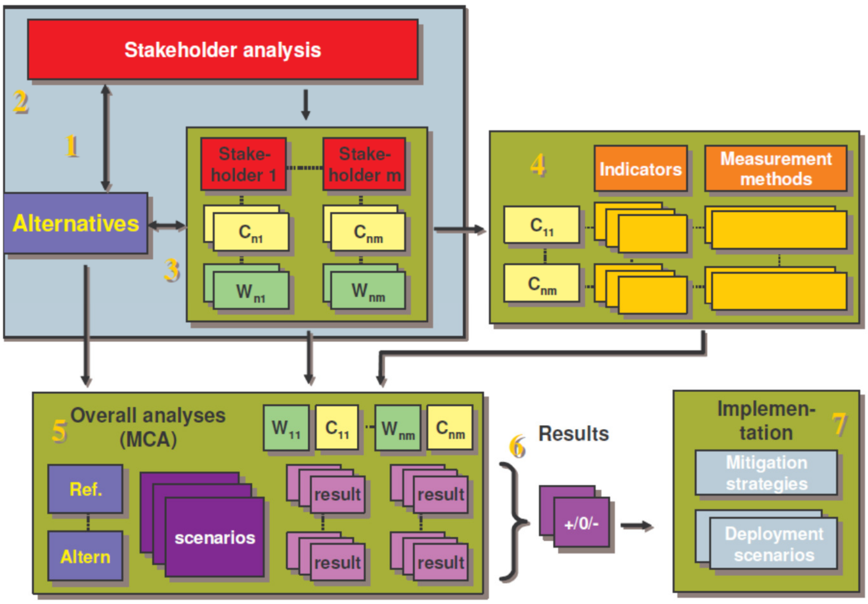

Figure 3.4. MAMCA methodology (Macharis, De Witte, and Ampe 2009).

As referred, stakeholders are included in a very early stage of the process, as it happens in the second of the seven steps of the approach (Macharis, De Witte, and Ampe 2009). Nonetheless, stakeholders can participate further ahead in the process, with inputs in the evaluation stage and provide personalized weights for the different criteria.

The process is briefly described in the following paragraphs (for more detail, see Macharis, De Witte, and Ampe (2009 and Macharis, Turcksin, and Lebeau (2012)).

ALTERNATIVES DEFINITION

The methodology starts with the problem definition and the definition of its possible solutions (alternatives). These alternatives can represent, for instance, different investments, scenarios, and policies.

STAKEHOLDER ANALYSIS

At this stage, stakeholders are selected and profiled. Every stakeholder that may affect the decision, or be affected by it, should be included in the process. Besides, they should be profiled, in order to understand their objectives and wishes. Their participation will help to refine previously defined alternatives. Only by choosing the right stakeholders, is it possible to define relevant alternatives.

CRITERIA AND WEIGHTS DEFINITION

The criteria will be defined by the stakeholders themselves and should reflect the stakeholders' goals, while the weight of each criterion is the importance that each stakeholder gives to each goal. Likewise, weights should be given to each stakeholder group. This will show the importance given to each stakeholder group. For instance, the local authorities' perspective may have higher importance than the citizens' perspective. In the case that all groups are treated as having the same importance, stakeholders' weights should be same.

INDICATORS AND METHODS SELECTION

After defining the criteria, indicators to measure those criteria should be chosen. There can be more than one indicator for the same criterion, and one indicator can be used for more than one criterion.

Overall analysis and ranking

Based on previously defined criteria, alternatives are evaluated. This can be done by using a table to compare all alternatives, but it can depend on the evaluation method chosen *a priori.* After evaluation, alternatives should be ranked.

Results

After the evaluation, alternatives are classified. But a sensitivity analysis should be performed to assess the robustness of the classification. At this point, it is possible to understand the positive and negative impacts that each alternative has on each stakeholder group.

Implementation

To finalize, the implementation process should be planned. When choosing implementation paths and deployment schemes, it is desirable that the points of view of the stakeholders are not lost along the way.

3.2 Service design

Service design methods emerge from the service science research, an interdisciplinary scientific discipline that brings together engineering and management concepts, with many ideas being adapted from marketing, information systems, and process-oriented management (Furrer et al. 2016; Grenha Teixeira et al. 2017; Ordanini and Parasuraman 2011). Concepts such as service innovation, service design, and service-dominant logic have emerged throughout the years, laying the foundations for service research (Lusch and Nambisan 2015; Patrício et al. 2011; Vargo and Lusch 2008).

Maglio et al. (2009) refer to service systems as the *"abstraction of the 21^st^ century"*. In their work, they state that *service* can be defined as the application of resources that results in changes in the system and creates value for both service provider and customer. In the service science domain, a *system* is a configuration of *resources*, which are not only physical resources but competencies, skills, and knowledge. *Service systems* can then be described as *"dynamic configurations of resources"* (Maglio et al. 2009).

Service design is usually considered a stage of the design of new services, but it became a methodological approach to innovation (Grenha Teixeira et al. 2017; Furrer et al. 2016). Hence, service science can be considered the umbrella of services research, where service design methods are used to achieve service innovation by applying a service-dominant logic (S-D logic).

As research evolves, concepts mature, and different frameworks emerge to incorporate new concepts. Vargo and Lusch (2008) discuss fundamental concepts such as *value co-creation* (service does not have value on itself and requires at least two persons) and present the fundamental premises of S-D logic (Table 3.4).

Table 3.4. Service-dominant logic foundational premises (FP) (adapted from Vargo and Lusch 2008)

FP1	Service is the fundamental basis of exchange.
FP2	Service (singular) is only now becoming more apparent with increased specialization and outsourcing.
FP3	Indirect exchange masks the fundamental basis of exchange.
FP4	Goods are a distribution mechanism for service provision.
FP5	Operant resources are the fundamental source of competitive advantage.
FP6	The customer is always a co-creator of value.
FP7	The enterprise cannot deliver value, but only offer value propositions.
FP8	A service-centred view is inherently customer-oriented and relational.
FP9	All social and economic actors are resource integrators.
FP10	Value is always uniquely and phenomenologically determined by the beneficiary.

These premises provide the basis for developing frameworks such as the S-D logic framework proposed by Lusch and Nambisan (2015) that considers four meta-theoretical foundations (Figure 3.5): *actor-to-actor networks; resource liquefaction; resource density*; and *resource integration*.

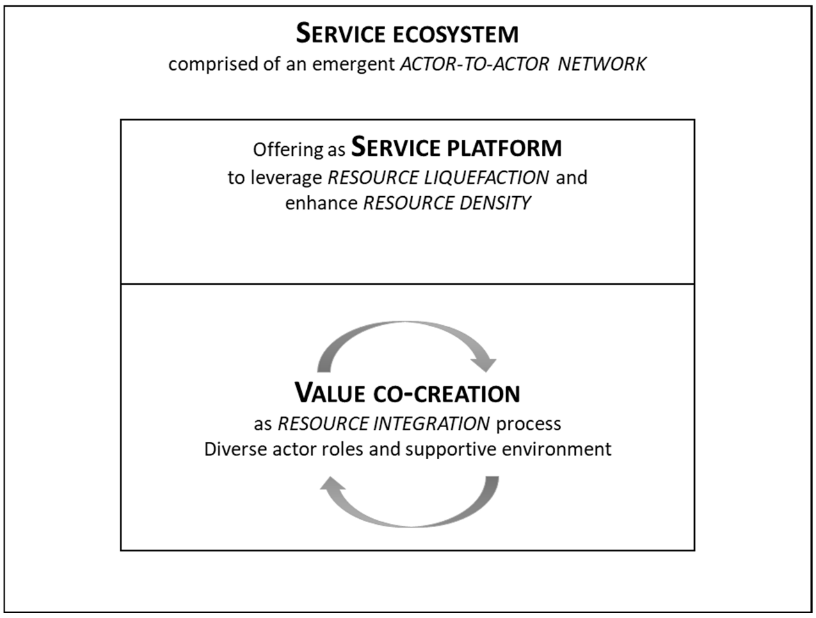

Figure 3.5. Tripartite framework of service innovation (Lusch and Nambisan 2015).

ACTOR-TO-ACTOR (A2A) NETWORKS

Actor-to-actor networks provide a network-centric perspective to S-D logic since they allow to go beyond traditional dyadic roles of the service provider and customer. Any interaction between two actors (stakeholders) implies the creation of value for the system.

RESOURCE LIQUEFACTION

S-D logic considers that digitalization has potentiated the decoupling of information from its physical form, since new digital processes allow for information to be easily shared. These changes create opportunities for new social connections and foster innovation.

RESOURCE DENSITY

If a service is the application of resources to create value, the more resources one has available (higher density), the more value one can create.

RESOURCE INTEGRATION

In S-D logic, resources are all possible sources of value (technology, people, knowledge, information, etc.). Value can only be created by using a combination or bundle of resources (e.g., knowledge + technology, skills + people). Innovation results from recombining existing resources.

The framework incorporates three inter-related elements (Lusch and Nambisan 2015):

1. *Service ecosystems* relate to the emergent *actor-to-actor networks* that are created by stakeholders' interactions through which value is exchanged and co-created.
2. *Service platforms* improve the service quality by *liquefying resources* and increasing *resource density*, thus facilitating access to proper bundles of resources and potentiating innovation.
3. *Value co-creation* sees value on the result of the interaction between the service provider and the service beneficiary (i.e., customer) that uses *integrated resources* through mechanisms that support the service delivery process.

SERVICE ECOSYSTEMS

Service ecosystems are related to the organization that results from the interaction of the different actors (stakeholders) in the community. Actors include all entities (organizations or individuals) that depend on one another, and are connected through shared institutional values and logics.

SERVICE PLATFORMS

Service platforms are considered the venue for service exchange, facilitating the interaction of actors and resources. Service platforms create the conditions for service exchanges, where goods/devices become distribution tools.

VALUE CO-CREATION

Value co-creation exists when actors, who play different roles in the ecosystem, integrate resources to generate value. The internal processes (activities) of the actors support the value creation process, facilitating interaction among other actors. Therefore, opportunities are generated for other actors to mutually create value.

In the new technology-enabled service context, there are plenty of channels, social media, and smart services, through which customers and service providers interact. According to the S-D logic, value is co-created with customers as value-in-use. Irrespective of the degree of intangibility involved in a given offer, "the customer is always a co-creator of value" (Vargo and Lusch 2008). Customers take on, therefore, an active, connected, and informed role in the value creation process. This paradigm is opposed to the traditional goods-dominant (G-D) logic, which considers customers as passive consumers and where goods are created by firms and distributed to consumers (Vargo and Lusch 2010).

Therefore, the success of digital solutions adoption strongly depends on the correct (re)design of processes and the implementation of a user-centred mindset. Users and other stakeholders are engaged and encouraged to share and use their experiences as a way to generate more effective and meaningful solutions (Holmlid 2012).

In fact, the developments of information and communication technologies (ICT) have provided several opportunities for service research and, at the same time, have benefited from contributions from service innovation. A few examples are: (1) the *service* concept used to categorizes information systems as information services, thus contributing to innovate service delivery processes; (2) the client interfaces and the digital platforms that relate to human-computer interaction research; (3) intra- and inter-organizational service delivery systems that are possible due to the IS support in innovating business processes; and (4) the digital infrastructures that provide other channels for service provision (Barret et al. 2015).

Considering further research in service design, Ostrom et al. (2015) identify eight subtopics under the "leveraging service design" research priority. One of those topics consists of "involving customers through participatory design and codesign to enhance service experience". In line with these concerns, this work aims at exploring more active ways to engage public transport customers in the service design process. Customers have valuable knowledge and opinions and they are, in general, willing to contribute to the decision-making processes. At the same time, they wish to share their experience and participate in the service delivery process. However, the potential of these contributions is often overlooked, and methodologies that enable effective customer participation are missing. In the end, if their contribution is not recognized or encouraged, customers quickly lose motivation and give up participating.

To successfully implement the S-D logic in the design of new services, methods should offer a way to create well-defined procedures. A well-designed service with a proper workflow assures the efficiency of the service (Davenport 1993) and helps to manage customers' expectations by understanding their perception of service quality (Zeithaml, Berry, and Parasunaman 1993).

Furrer et al. (2016) identify four groups of methods in service research to help the design and development of new services, namely: blueprinting, service quality measurement (SERVQUAL), experience prototyping, and co-creation and service innovation.

Methods such as Multilevel Service Design (MSD) apply those methods in one single approach, to foster innovative service design (Patrício et al. 2011). Service Design for Value Networks (SD4VN) takes on MSD and adds a network perspective to the service system (Patrício et al. 2018), also incorporating experience prototyping experience through the Customer Experience Modelling method (Grenha Teixeira et al. 2012). These methods have, in fact, evolved, integrating models and artifacts used in marketing, operations management, decision-making, and IS (Grenha Teixeira et al. 2017). In the next sections, we briefly describe the main characteristics of these methods.

3.2.1 MULTILEVEL SERVICE DESIGN

The complexity degree of services has been increasing, with the involvement of different stakeholders, different resources, and different interaction channels. A service can, therefore, be seen as a service system with subsystems. In other words, a customer has several ways to interact with the main service – service system – as if each interaction was a different service – a subsystem (Patrício et al. 2011).

The coexistence of different interfaces is related to technology evolution and has led to the creation of multi-channel services, leading to the paradigm of multi-channel services design and management (Grenha Teixeira et al. 2017). Facing new technology and higher customer demands, service innovation became dependent on bringing together synergies from different domains. It is in this context, and due to the lack of unifying methods, models, and languages, that the Multilevel Service Design (MSD) method was created (Patrício et al. 2011)

MSD is a method that enables the participation of different stakeholders (Patrício et al. 2011), and that can be used to design multi-interface services in complex contexts (Patrício, Fisk, and Falcão e Cunha 2008). In creating and developing efficient IS for both authorities and citizens, MSD is expected to strongly improve communication.

MSD is structured in three layers (Figure 3.6): a strategic level (the *service concept*); an intermediate level (the *service system*); and a detailed operational level (the *service encounter*). The focus is on the customer experience, with the customer being involved in all design stages, through a comprehensive co-creation environment (Patrício et al. 2011).

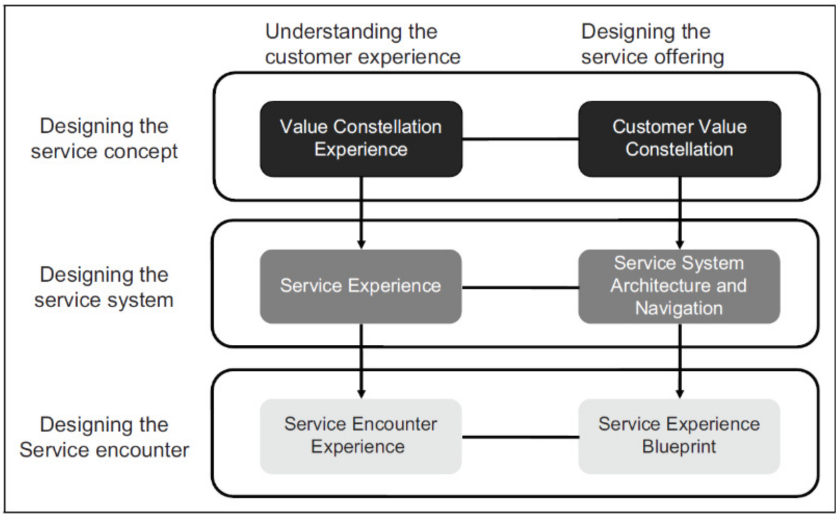

Figure 3.6. Multilevel Service Design scheme (Patrício et al. 2011).

The *service concept* specifies the value offered. When designing a service, this stage is related to defining core and supplementary services (Patrício et al. 2011). Then, the *service system* details the activities performed by the customer, that require interaction with the service provider, and the interfaces by which that interaction occurs. The results are the organizational matrices (Figure 3.7) – Service System Architecture (SSA) and Service System Navigation (SSN).

The SSN represents the customer journey. The customer journey describes all the customer activities to reach the desired service, leading to a good or bad *service experience* as a result of all the interactions with the service provider at all times and in every interface (Patrício et al. 2011).

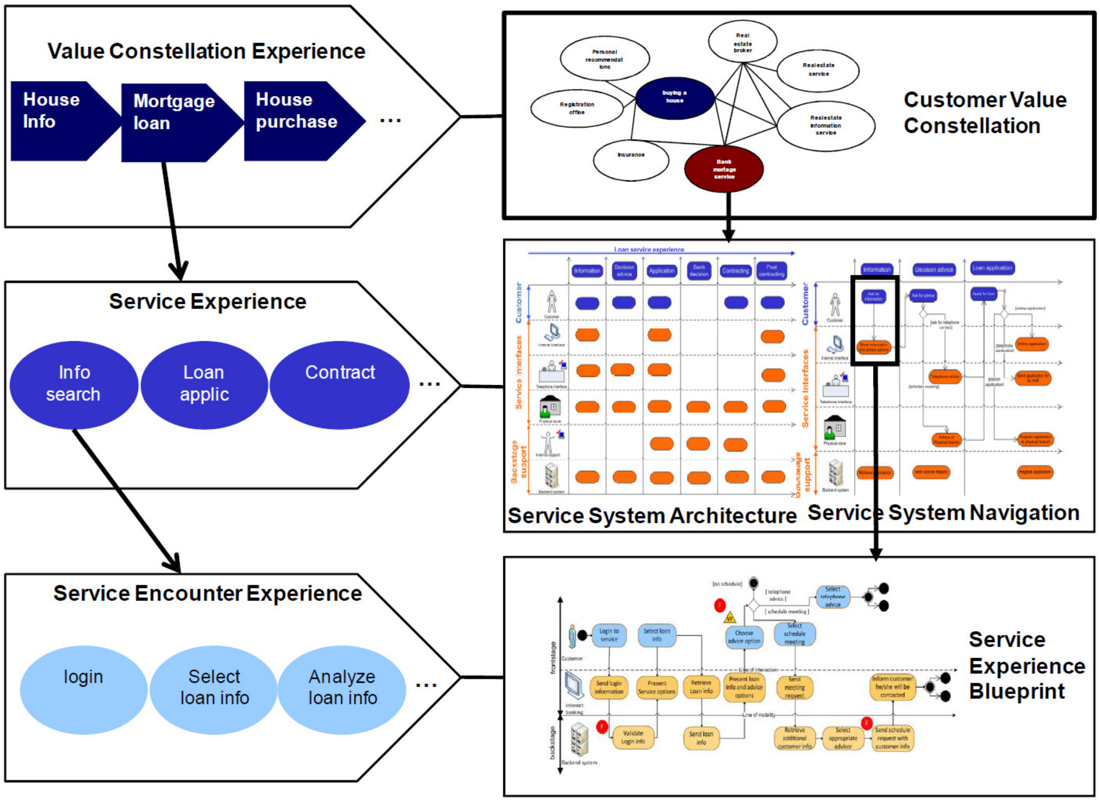

Figure 3.7. Multilevel Service Design artifacts (Patrício et al. 2011).

Some MSD features are related to the Business Process Management (BPM) approach (Table 3.5), but they have been adapted to increase awareness about the customer experience. As MSD may not fully respond to the requirements of the complete system design process, it can be merged with other approaches. In fact, in a previous work where this method was applied to information system design (Duarte 2014), MSD was integrated with BPM (Figure 3.8).

Table 3.5. Relation between the BPM and the MSD approaches.

Business Process Management	Multilevel Service Design
Value proposition	Value Constellation Experience
	Customer Value Constellation
Responsibility Matrix	Service System Architecture
Process Map	Service System Navigation
Process Model	Service Experience Blueprint

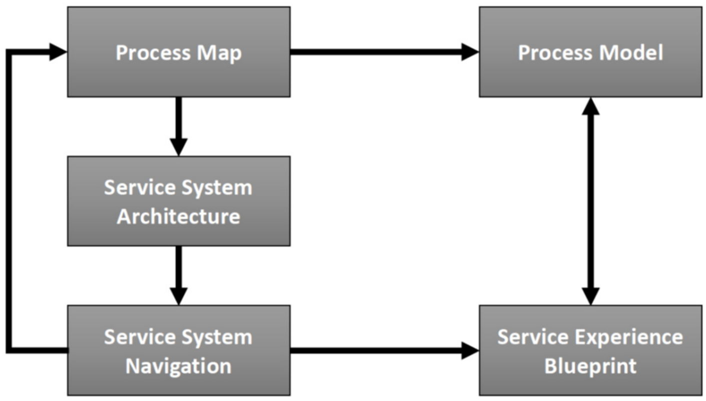

Figure 3.8. A methodology based on BPM and MSD artifacts (Duarte 2014).

3.2.2 SERVICE DESIGN FOR VALUE NETWORKS

While MSD considers the dyadic interactions between the service provider and customers, the Service Design for Value Networks method (SD4VN) was developed considering the current complexity of service systems and the importance of value co-creation at the network level (Patrício et al. 2018; Lusch and Nambisan 2015). As so, SD4VN shifts from dyadic interactions to contexts with many-to-many interactions. It can be seen as an extension of MSD (Patrício et al. 2011) that integrates other contributions such as Customer Experience Modelling (CEM, Grenha Teixeira et al. 2012).

This method considers the same multilevel approach of MSD, but the main differences are at the strategic level during the design of the service concept. The process starts by mapping the value network, which includes building the *actor-network map* to identify relevant actors and their relationships in the system context. Then, resorting to goal-oriented analysis, the second stage of the process is *understanding multiple actor experiences and interactions*, resulting in the customer experience model. Finally, the *value network service concept* and the *service encounters* are designed in the third stage, following the same approach of the MSD (Figure 3.9).

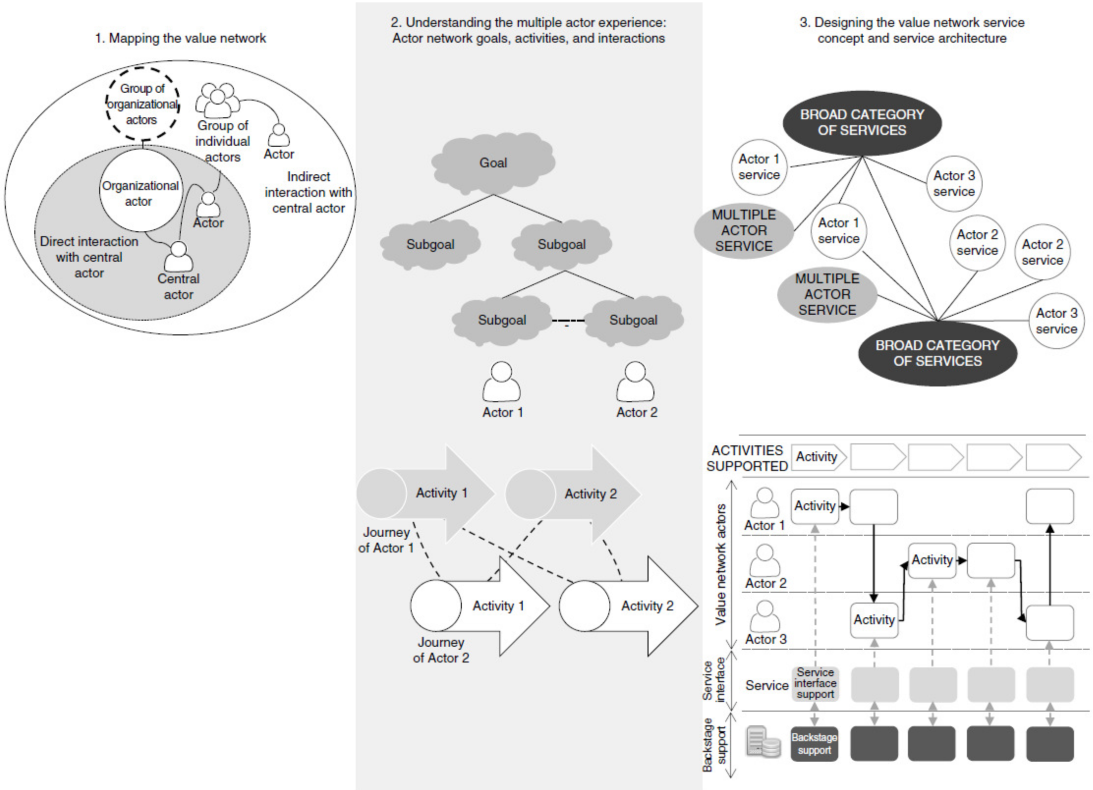

Figure 3.9. Service Design for Value Networks artifacts (Patrício et al. 2018).

Besides the network perspective of this method, it is important to highlight the fact that it incorporates the customer experience through CEM (Grenha Teixeira et al. 2012; Patrício et al. 2018). Understanding the activities of customers even before designing the service assures that the value proposition will be aligned with the expectations of the customers, thus improving their experience.

3.3 Information Systems

With the increasing levels of digitalization, reinforcing the technological perspective in any organization or institution is key to keep up with the evolution of information and communication technologies, and in this way continuously improving efficiency.

In the transportation sector, considering enterprise architecture frameworks (EAF) and information systems architecture (ISA) design methods helps improve business processes that take advantage of current technological capabilities.

For many organizations, methods to include technologies in service improvement have been used since the 80s. Business process redesign and EAF, based on technology, have been applied in the education and the health sectors to improve performance and interaction with customers (Ahmad, Francis, and Zairi 2007). EAF is used with business process management as a way to align processes with information technologies (Malyzhenkov, Gordeeva, and Masi 2018).

Moreover, since the mid 90s it has been widely accepted that companies should have a technological-focused strategy, with concerns related to stakeholders and the environment. In the UK, institutions were encouraged to implement new IS management systems by developing Information Strategies (Allen 1995). Enterprise Resource Planning (ERP) and Customer Relationship Management (CRM) systems started to migrate to the public and services sector, with many examples in health and education (Pollock and Cornford 2004).

Being one type of Management Information Systems (MIS), an ERP is a modular management software that allows the integration of several applications used to manage people, resources, and activities. The ERP systems originated from the industrial sector with Materials Requirements Planning (MRP) systems and, later, with Manufacturing Resource Planning (MRP II) systems. Their versatility became one of the most important factors for their use in several contexts. CRM, as the name suggests, is not only a resource but a concept used for managing the relationship with customers. It usually has an important role in attracting and retaining customers.

In practice, the integration of ERP and CRM systems seems useful, since data collection and data analysis are essential to achieve good results when improving customer relationships. These systems can give the company a wide sample of information that can be used to develop new capabilities and competencies (Piedade and Santos 2008).

Moreover, Decision Support Systems (DSS) can also be viewed as MIS. A DSS is, in general, based on optimization and simulation algorithms that provide information to decision-makers in order to help them in complex decision processes.

In the context of transportation and mobility, there are examples of all these types of software for the different stakeholders dealing with urban-related problems. For instance, municipalities may resort to CRM to improve digital support to citizens, with processes based on an internal ERP to manage municipality resources. Or, for example, urban planners, mobility planners, and transport operators may use some kind of DSS to design transportation networks and manage their operations.

In another direction, big data grew interest in the potential value of the information available in many services, creating opportunities for information systems to move from a management support perspective towards a broader concept of information systems, the so-called knowledge-based systems. These systems explore the potential for knowledge co-creation using data collected from customers, e.g., retail, online services, etc. (Zaraté and Liu 2016; Grover et al. 2018). The potential of big data has also proven to improve decision-making in many other sectors (Zhang 2017; Acharya and Singh 2018).

It should be noted that the design of information systems requires a structured approach in order to ensure processes are aligned with the objectives of the organization. During the last decades, several methods and frameworks have been developed with these concerns. And, more recently, new frameworks have been focusing on issues related to big data and to the existence of multiple data sources (Rajapaksha et al. 2017; Tekiner and Keane 2013). Tekiner and Keane (2013) state that more classic frameworks such as the Zachman Framework, TOGAF, and Gartner's methodology are still able to provide the proper approach to IS projects.

In the next sections we discuss the characteristics of some generic frameworks that emerged in the end of the 20th century. Namely, the Zachman Framework, that is one of the most well-known frameworks; the TOGAF, that is an adaptation of the Department of Defense's Technical Architecture Framework for Information Management (Urbaczewski and Mrdalj 2006); the FEAF that was created because US Government was following the trends of the industry; and Gartner, that has a higher focus on strategy. In the end we include some considerations about the Enterprise Architecture Design, that is based on the Enterprise Architecture Planning method plus several characteristics of previously mentioned frameworks.

Other works refer other frameworks such as the Treasury Enterprise Architecture Framework (TEAF) and the Department of Defense Architecture Framework (DoDAF, Urbaczewski and Mrdalj 2006; Lim, Lee, and Park 2009). We did not include these frameworks in our analysis since we already consider the FEAF, that is also a result from the work of the US Government.

3.3.1 Enterprise Architecture Frameworks and Information Systems Architectures

An Enterprise Architecture (EA) framework has the objective of mapping the software development processes for an enterprise and their relations and interactions (Urbaczewski 2006). In practice, it is a group of artifacts and objects that are important to represent the enterprise, and are used to support the business software development, implementation, and management, mainly during a period of change (Velho 2004).

Enterprise Architectures emerged as a form of aligning information technologies (IT) with the companies' processes. In order to turn IT into a facilitator of the processes, IS should be defined according to the company's strategy and needs. An EA can be seen as a *"blueprint for system and the project that develops it"* (Urbaczewski and Mrdalj 2006) or, in other words, as a bridge between strategy and implementation, bringing together a Business Architecture and an Information Systems Architecture (Velho 2004).

The main goal of an information system framework is to help companies define how to implement business strategies by using IT. The EAF analysed in this work have different foci and approaches. Due to some misinterpretation of the term *framework* and for a clear understanding of the following sections, we consider here that frameworks provide the structure for a project, defining the artifacts to be used in different contexts, while methods or processes define a step-by-step approach to the design of artifacts.

Those artifacts may include business process models since many frameworks have a business process-oriented approach to foster innovation. Business process models are used in business process management (BPM) and reengineering approaches to improve efficiency and effectiveness of internal tasks (Davenport 1993). The tools used in BPM help redesign tasks while introducing technological advances, so companies can maintain their goals while innovating in how to achieve those goals (Trkman 2010). In fact, process innovation has shown to be quite helpful in terms of costs and time, and in increasing service level (Davenport 1993).

3.3.2 THE ZACHMAN FRAMEWORK

The Zachman Framework for Enterprise Architecture is considered the first Enterprise Architecture (EA). Zachman first described his work as "Framework for Information System Architecture", but as it represents the enterprise and not only the information systems, it was renamed to "Framework for Enterprise Architecture" (Sessions 2007). The need for a framework at the time (1987) was justified by the increasing complexity of IS and the dependency of enterprises on those systems (Urbaczewski and Mrdalj 2006).

This framework is based on the comparison of the construction of a IS to the construction of a building. The original framework presented five perspectives, from the owner of the project to the sub-contractor, like in a physical construction, including the planner, the designer, and the builder (Velho 2004; Urbaczewski and Mrdalj 2006; Spewak and Hill 1993; Sessions 2007). For each of these perspectives, it suggests the artifacts and models that will answer some questions (abstractions) about the project: *what*, *how*, *where*, *who*, *when*, *why*. This type of organization makes Zachman's Framework easily understood by cross-functional teams. It can be shown as a matrix (Figure 3.10) in which the perspectives of each player can be associated to the rows and each question to one column. Each stakeholder's perspective is associated with a level of detail, that increases when moving vertically from top to bottom (Sessions 2007; Zachman 2011). Zachman, himself, mentions the fact that no architecture is completely right or completely wrong; therefore, architectures and frameworks need to be used together (Sessions 2007).

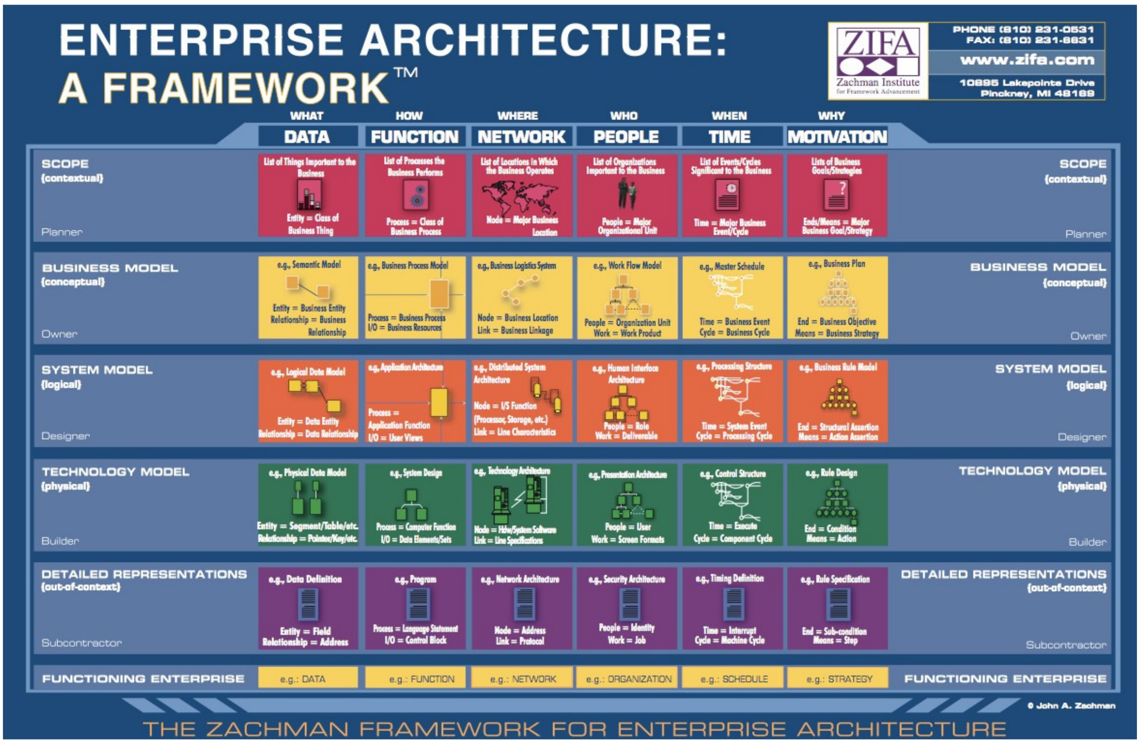

Figure 3.10. The Zachman Framework for Enterprise Architecture (Zachman 2011).

The planner’s perspective is related to the business context. At this level, project leaders are supposed to define the mission, vision, and objectives that must be kept in mind during the development of the IS. In urban mobility, this perspective should reflect the vision and the purposes of the city. The owner's perspective reveals how the goals previously defined can be achieved. Models should reflect the conceptual design of the system, presenting business processes to be supported by the system. The designer's perspective is a more detailed plan of the owner's perspective, thus presenting the first plan of the product as an architect would design it. Then, the builder's perspective includes the physical models. If in the case of a building engineers detail all the specifications of the materials, in the IS context, the data application, and technological architectures are defined by technicians. The subcontractor’s perspective represents configurations “out of context”, i.e., details of parts and components of the IS.

The coexistence of the different perspectives is one of the reasons for this framework's success. In fact, it has currently more than one version. It was recently modified to include what some call the user perspective (Urbaczewski and Mrdalj 2006; Zachman 2011), being related to operations to be performed.

It can also be used as a basis for other purposes than IS development, such as to support decision-making processes (Danny et al. 2019; Malyzhenkov, Gordeeva, and Masi 2018).

3.3.3 TOGAF – Architecture Development Method

The Open Group Architecture Framework (TOGAF) divides an EA into four categories, that, in some aspects, may remind Zachman's perspectives due to the different levels of detail (Sessions 2007):

1. Business Architecture – is related to processes
2. Application Architecture – is related to IS applications
3. Data Architecture – is related to entities
4. Technical Architecture – is related to software and hardware

The most important part of this framework is the Architecture Development Method (ADM) that suggests rules for developing principles for architectures (Urbaczewski and Mrdalj 2006). The Open Group approaches the EA as if it was a continuum of architectures, going from a higher level to a more detailed level of specification.

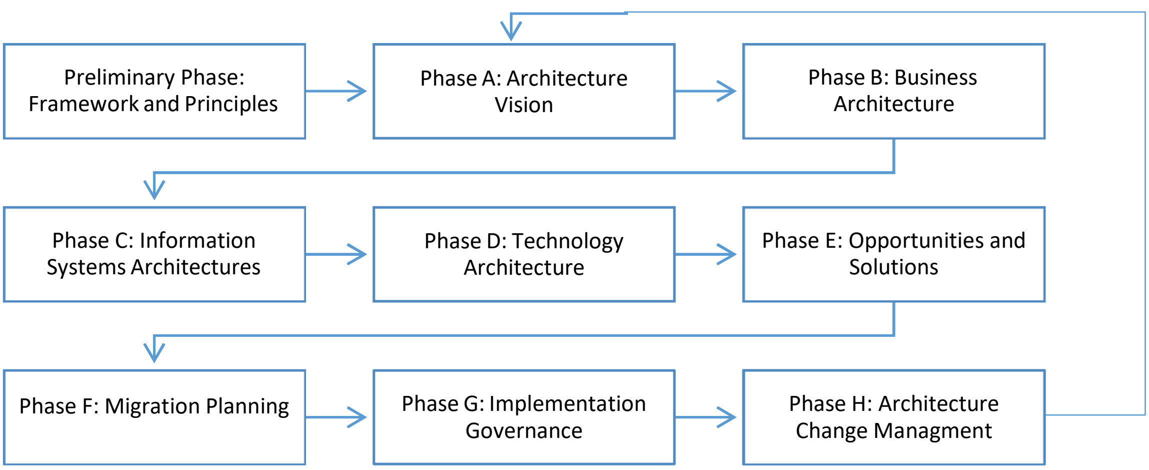

Figure 3.11. The TOGAF Architecture Development Method (Sessions 2007).

The ADM is the process that helps the definition of each architecture. In the ADM, TOGAF proposes a sequence of phases to implement the architecture or its change (Figure 3.11), but the order can be modified according to the needs and specifications of the project. The only aspect that is mandatory is the Preliminary Phase to define the project, its principles, and adaptations from ADM. The scope and phases must be clear to everyone involved in the project. Since TOGAF intends to be highly adaptative, phases can be ignored or reordered. The only phase that shall be always present is Phase A since the vision should be known before starting to create any of the sub-architectures (Sessions 2007).

3.3.4 Federal Enterprise Architecture

The Federal Enterprise Architecture Framework (FEAF) comes from the US Government to manage its agencies as single entity, by creating a unique EA. Compared to the previous frameworks, it is more complete, since it includes a taxonomy such as Zachman Framework and a process such as TOGAF (Sessions 2007). The FEAF defines EA as *"a strategic information asset base"*, that defines mission, business activities, the information requirements to perform operations, and technologies that support those (Lim, Lee, and Park 2009).

According to Lim, Lee, and Park (2009) can be considered a combined framework as it describes both the elements of the enterprise and the procedure for its implementation and maintenance.

Table 3.6. FEA process steps and brief description (Sessions 2007).

1	Architectural Analysis	Vision definition and association with an organizational plan
2	Architectural Definition	Architectural definition of the desired segment, goals' performance documentation and EA development
3	Investment and Funding Strategy	Funding strategy selection
4	Program-Management Plan and Executive Projects	Management and implementation plan creation

The FEA process, which is also a step-by-step approach of the implementation of the EA starts by creating a segment architecture for an agency, i.e., a department of the enterprise. At a high level, it can be described in four steps (Table 3.6). These four steps can be associated with TOGAF's phases, from the analysis of the vision and strategy to the implementation, including the architecture itself (business, data, services, and technology), investments and management plans (Sessions 2007).

3.3.5 GARTNER'S FRAMEWORK

Gartner's framework is more concerned with practice than processes or taxonomies, as these are only tools used to implement an EA. The practice is the correct way of using those tools.

For Gartner, "architecture is a verb, not a noun" (Sessions 2007). This means that the definition and implementation of an Enterprise Architecture is not a moment in the company's life but a process that includes the creation and maintenance of the EA.

The focus of this framework is the strategy. For Gartner, bringing together business owners, information specialists, and technology developers is crucial at the beginning of the process of the design of the EA. When theses groups of stakeholders share the same vision, the chances of a successful implementation are higher. In other words, it does not matter what process is followed if the goals are not well defined. The strategy is the path to go through to get to the goals (Sessions 2007). Then, it is possible to define the tools to implement such a strategy. As mentioned, those tools can be other frameworks.

Sessions (2007) summarizes Gartner's view by stating that the two most important things are *"where the organization is going and how it will get there"*. So, it is not about engineering but about strategy. The idea is to have in one organization, one strategy vision common to all members. Clearly, the involvement of the leaders will be crucial when defining the strategy.

3.3.6 ENTERPRISE ARCHITECTURE DESIGN

The Enterprise Architecture Design (EAD, Velho 2004) considers the strengths of other frameworks (Zachman, TOGAF, and FEAF), and is also based on the Enterprise Architecture Planning (EAP, Spewak and Hill 1993), adding more detail in certain phases. Taking into account that the EAD provides both a description of the EA and a step-by-step procedure to design and implement the IS, some researchers might consider it a method rather than a framework. According to the classification of (Lim, Lee, and Park 2009) EAD would be a combined framework.

Due to the similarities between the EAD and the EAP we organized the phases of the EAD (Figure 3.12) in the same four main phases of the original version of the EAP (Spewak and Hill 1993). The first main phase focuses on planning the project and defining the vision for the EA. The second phase describes business processes and current supporting technology. In the third phase the IS' new requirements are defined. Finally, the fourth and last phase presents the plan for implementation, considering a transition period between the existing and the new systems.

A unique characteristic of the EAD is the presence of the two *policy architecture* phases. Even though those phases are not directly related to the main phases, we include them in the situation to be implemented as they describe management principles to be adopted in the new EA (Velho 2004).

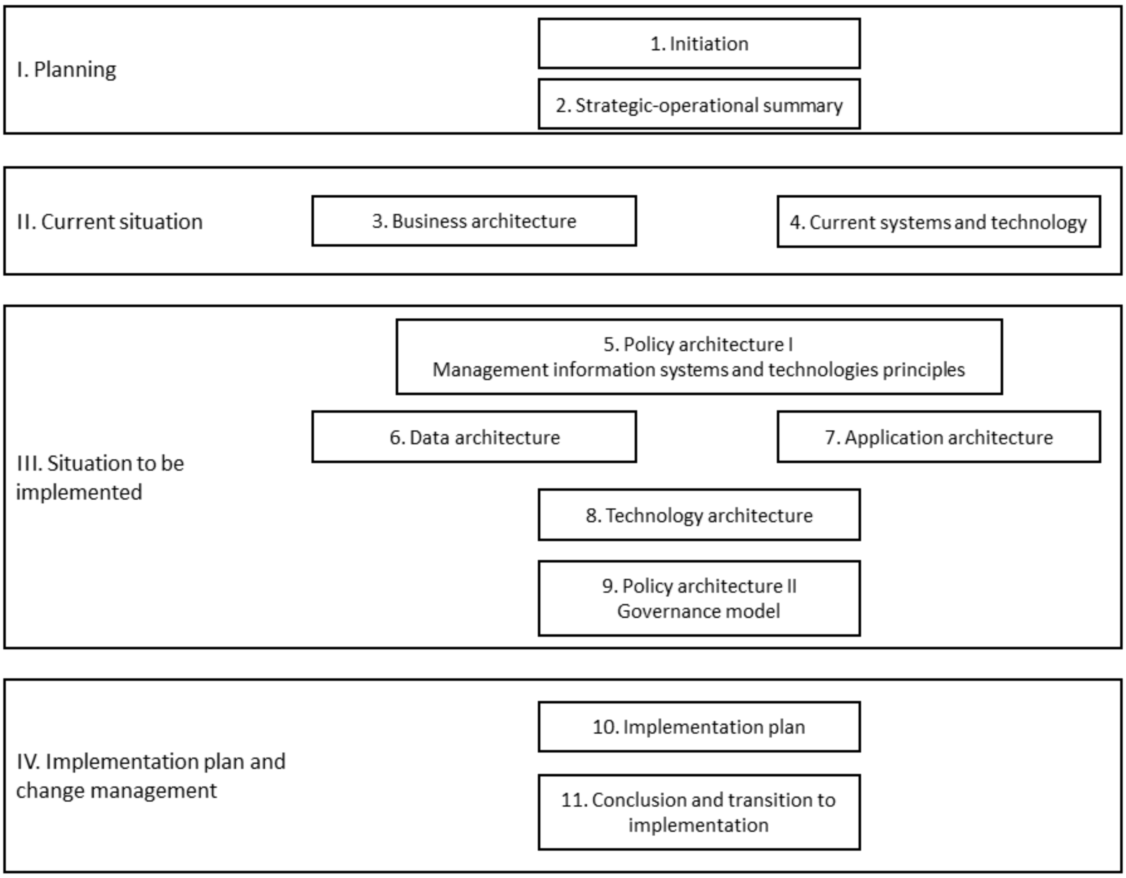

Figure 3.12. Enterprise Architecture Design (Velho 2004).

As other frameworks, the EAD starts by planning the implementation project with the definition of the methods to be used and the work plan. Then, Velho (2004) suggests the creation of the *strategic-operational summary* that contains the vision and goals of the EA that will be supported by the new IS. Here are included the *change factors* that state the desired changes to implement (Velho 2004). While the objectives and goals refer to what the company aims to achieve, the *change factors* can be associated with the strategy to be implemented so that those objectives are achieved.

In the current version of the EAP (Figure 3.13), the p*lanning initiation* phase is detached from the process, representing the preparation for the entire project. Consequently the first phase, becomes more focused on the vision and principles to be adopted (Spewak and Tiemann 2006), which is in a certain way similar to the *strategic-operational summary*. However, stressing the change factors becomes an advantage of the EAD.

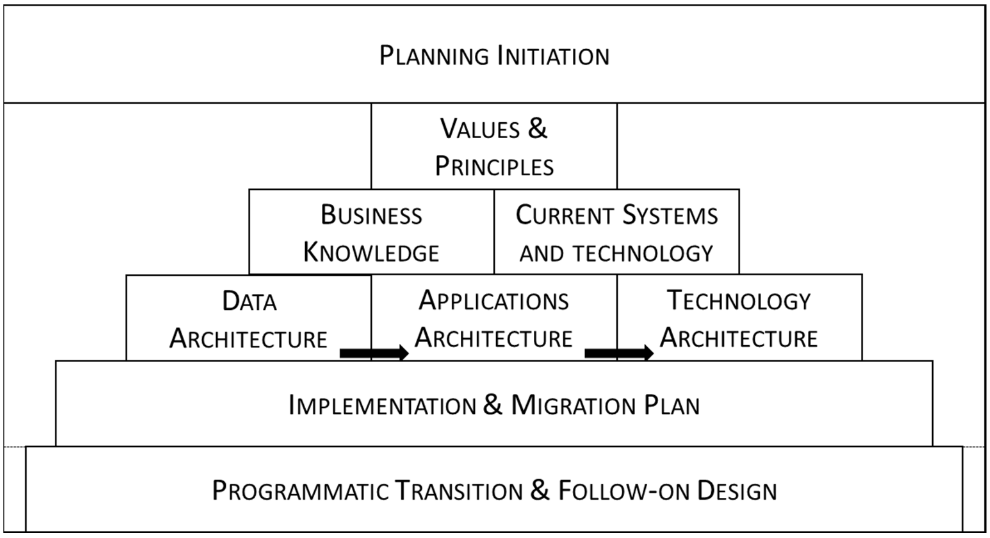

Figure 3.13. Enterprise Architecture Planning(Spewak and Tiemann 2006),

When compared to other frameworks, instead of only describing the new processes and technologies, the EAD considers that there is an existing context. This is achieved during the phases *business architecture* and *current systems and technologies*. Understanding the current situation is very important in the urban context because there are several existing processes that are imposed by local laws. Analysing the current processes is necessary to understand what can and cannot be changed. Moreover, analysing the existing technology is also important. Due to low public budgets, municipalities need to take the most possible advantage from the existing IS.

The remaining stages are quite similar to the TOGAF, starting with the definition of the data architecture until the implementation plan, including the application architecture and the technology architecture. The data architecture phase includes the definition of the business entities, their description, and the relationship they have with the business processes. Moreover, the data architecture describes the data repositories. The application architecture describes the main applications of the IS, their relationship and description, and also establishes the relationship between the business processes and the applications. The relationship of both entities and applications with the business processes is established by identifying what entities and applications are part of the processes. Then the technological architecture describes the technological infrastructure that supports the data and the applications; and presents the plan for developing the systems components that will support the new processes (Velho 2004).

Finally, the governance model is detailed in the second *policy architecture*, before the *implementation plan*. The governance model distributes responsibilities about the maintenance of the architecture implemented. The level of complexity depends on the type of model chosen and the human resources available (Velho 2004). The importance of a maintenance plan is such that Spewak & Tiemann (2006) included a detached phase on the current version of the framework when considering the *follow-on design*.

This recommendation is also important for our work because, in the current socio-technical transition period, it is important to continuously maintain the IS to make sure it can respond to the high demanding digital processes.

Since the EAD is based on the Zachman Framework, some of its phases can easily be associated with the Zachman's abstractions (Velho 2004):

- the *strategic-operational summary* explores the motivations (*why*);
- the *business architecture* and *policy architectures* contribute to the abstractions *what*, *how*, *where*, *who*, and *when*;
- the data architecture, by describing entities and data structure, is associated with the abstraction *what;*
- the application architecture, by describing the process, contributes to the abstractions *how*, *who*, and *when*;
- the technological architecture, by describing the infrastructure, contributes to the abstraction *where*.

Velho (2004) considers that these contributions are all at the two top levels of the Zachman Framework (*context* and *business*). However, we consider that the recommendations and guidelines presented in the EAD may be used in lower and more technical levels of the Zachman Framework, depending on the detail of each architecture.

3.4 SUMMARY

This chapter presented a focused literature review covering the theory that supports the multidisciplinary approach and the framework proposed in this thesis.

The participation procedures described in section 3.1 show the importance of a structured approach to stakeholder participation, in transforming stakeholders from passive participants to active partners in public decision-making. Then, section 3.2 provides the theoretical background for adopting a service-dominant (S-D) logic in the urban context and presents service design methods that can support the multidisciplinary approach. Finally, the Information Systems theoretical background provides methods and tools for developing a conceptual framework to design technology-based services.

Together, the three topics provide the theoretical background for developing a novel multidisciplinary approach to urban mobility to foster stakeholder participation. Adopting an S-D logic and considering the concept of *city as a service system* (Polese et al. 2019), we propose the development of a conceptual framework following the principles of the Enterprise Architecture Frameworks presented above.

The main contributions of this literature survey for this thesis are as follows:

- The S-D logic framework proposed by Vargo and Lusch (2008) provides the foundation for the multidisciplinary approach.
- The Multilevel Service Design and the Service Design for Value Network methods provide the multilevel approach and the systemic approach to urban mobility. These methods ensure that concepts from the S-D logic are applied in the proposed approach.
- The Zachman Framework provides the holistic perspective of the city as an organization with multiple stakeholders, ensuring that all participants are represented.
- The Enterprise Architecture Design (EAD) provides the methodological approach to redesigning business processes while rethinking supporting information systems. The fact that EAD considers the complete process of redesigning an IS, incorporating the strengths of different frameworks (TOGAF, FEAF, EAP), led us to use only the EAD and the Zachman Framework in the remaining of the thesis.

4

AN INTEGRATED APPROACH TO URBAN MOBILITY

This chapter presents the components of this thesis that more directly relate to RO1 and RO2. Section 4.1 describes the multidisciplinary aspects of the proposed integrated approach, that results from the analysis made, in chapter 2, on the urban context. The outcome is a different strategic vision on cities, focused on inclusion and integration, thus leading to a city designed with everyone (integration of stakeholders) and for everyone (inclusion). This multidisciplinary approach sets the foundations for the framework presented in section 4.2.

This conceptual framework was designed based on the concerns and vision presented in section 4.1. The framework provides the structure and tools for the application of the proposed approach in a *socio-technical transition context*, encompassing methods from service design and information systems, as presented in chapter 3.

4.1 A MULTIDISCIPLINARY APPROACH TO URBAN MOBILITY

In their quest for sustainability, municipalities need to find solutions that adequately respond to the complexity of cities. Many options currently available (e.g., parking fees, electric vehicles, more public transport) focus on practical initiatives to reduce pollution but try to maintain the urban lifestyle developed in the last decades. However, if the resources available are scarce, achieving sustainability requires a radical change in the way we live and use the urban space. This change has been happening due to the awareness of younger generations regarding climate change and to the adoption of new technologies. Nonetheless, cities need to account for the needs of all generations and not only for the more technologically skilled people. Hence, the need to rethink urban systems, including urban mobility. Transportation is responsible for many of the negative impacts of urban life (pollution, congestion, noise, accidents, etc.), thus changing the paradigm of urban mobility is key in improving sustainability.

However, while implementing radical changes, we must be aware of the uncertainties of the future, and of the difficulty in changing cultural values. In fact, the need to rapidly implement radical changes is certain, and many governments and authorities are aware of that, as shown by the examples of European cities presented in chapter 2. However, in general, people do not change unless they understand they need to change. So, they should be guided towards change, while their current needs are still satisfied. Moreover, there is a high level of uncertainty regarding the future since socio-demographic changes are quite difficult to predict.

As shown in chapter 2, the evolution of cities is connected to the technological evolution of transportation and is, consequently, affected by mobility patterns. If transportation, cities, and technology are mutually impacted, then improving the efficiency of transportation systems requires an integrated and multidisciplinary approach in which the quality of life of citizens should be the main concern. Therefore, improving urban mobility requires changes in accessibility and land use, leading to new demand patterns instead of continually redesigning supply.

We can also conclude that many approaches focus on fostering a modal change whether it is from private to public transport, from fossil fuel vehicles to electric vehicles or to soft modes. These approaches are not fully inclusive and cannot be considered a solution for all citizens, because soft modes require some physical capabilities, public transportation supply will always be limited, and private cars cause congestion. So, when designing new mobility solutions, we suggest that urban and mobility planners go beyond the question “what do people want?” and consider “what do people need?”. As a result, some solutions may encompass changes in land use, creating proximity to services and increasing accessibility without changing mobility options. Taking into account this contextual analysis, the multidisciplinary approach proposed in our work considers four *dimensions*:

- urban;
- social;
- technological;
- and organizational.

The *social* and *urban* dimensions focus on people and their interactions and activities in the urban context. The *technological* and *organizational* dimensions are related to the processes supported by information and communication technologies. The *organizational* dimension also relates to decision-making processes as the organizational structure of the municipality (departments, divisions, etc.) impacts the flow of information until it reaches the decision-maker and/or the citizen. A good organizational structure (supported by an IS with the right workflows) will positively influence the efficiency of the decision-making processes.

The four dimensions proposed in this work consider the elements of the service-dominant (S-D) logic (service ecosystems; service platforms; and value co-creation) and the four meta-theoretical foundations of the framework presented by Lusch and Nambisan (2015): actor-to-actor networks, resource liquefaction; resource density, and resource integration.

Service ecosystems and *actor-to-actor networks* are visible when we compare cities to service systems and, as a result, deal with a network of stakeholders and their many-to-many interactions. The concept of *service platform* is present in the proposed holistic vision of the city as the place where service exchanges occur, and the consequent *resource integration*. Though S-D proposes the integration of resources, we consider integration refers to more than resources, and we propose the integration of the study of land use and mobility, the integration of different management levels and the integration of stakeholders (through active participation). Finally, the concept of *value co-creation* is also present in our approach, as participation of different stakeholders allows for the co-creation of information and knowledge about the city and transportation systems, thus creating value for the different stakeholders' groups. Those groups end up co-creating the city and its mobility services, by sharing decisions.

These concepts provide the support for the four dimensions and can be considered the pillars of the multidisciplinary approach: *city as a service system*; *integration*; and *co-creation* (Figure 4.1).

These three pillars result from the complexity of the urban context where multiple stakeholders interact and mutually influence behaviours and decisions. Understanding the *city as a service system* reinforces the idea that there are customers (those who benefit from the city) and service providers (those who are responsible for providing a good quality of life). Having *integration* as a main concern helps us in overcoming organizational barriers, pointing out the need to integrate resources (information, people, tools, etc.). Finally, fostering *co-creation* assures the development of a collaborative and participatory environment among stakeholders.

Moreover, the intersection of the proposed dimensions suggests that methods and tools from different research domains contribute to the practical application of this approach (Figure 4.1).

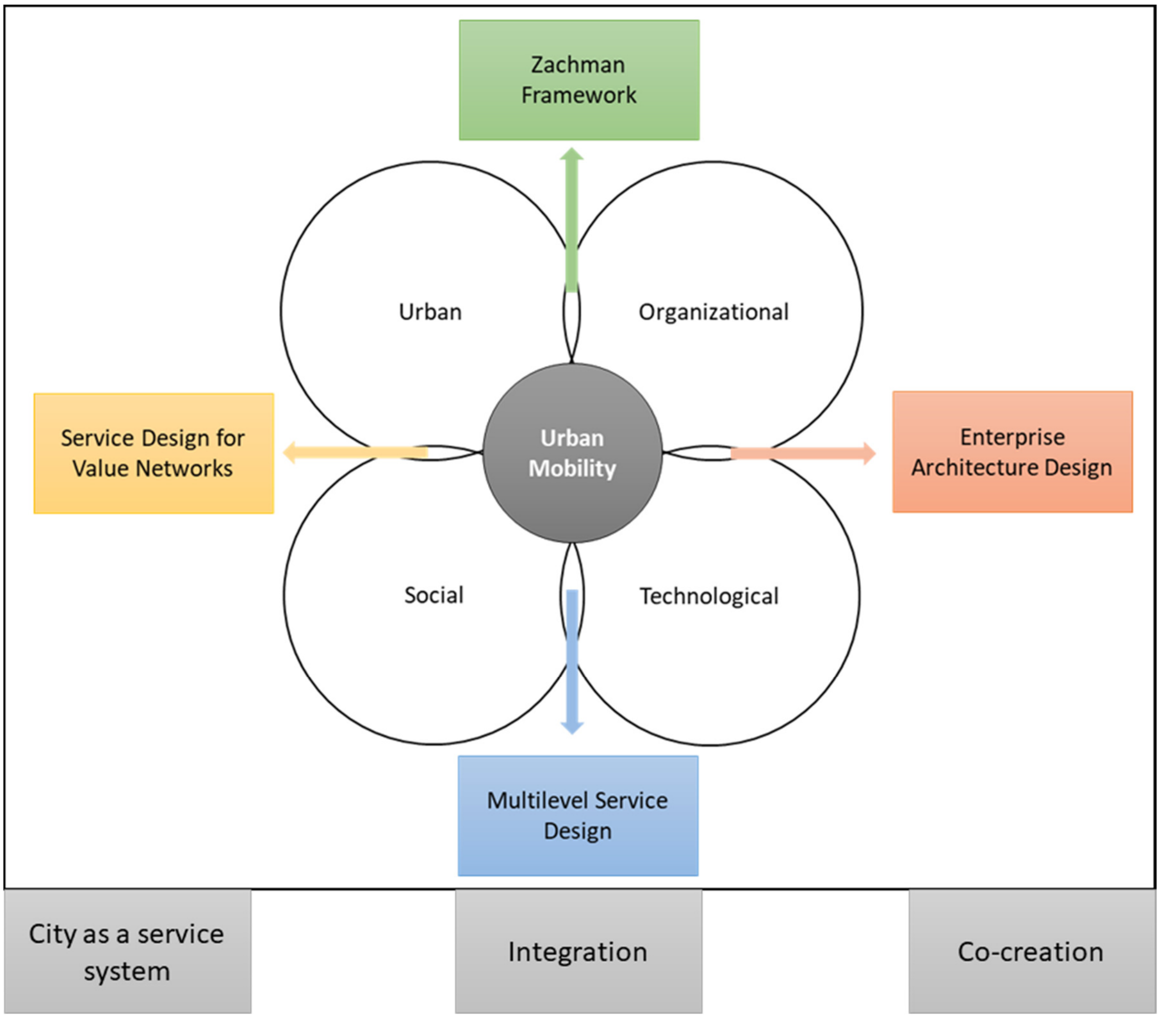

Figure 4.1. Multidisciplinary approach to urban mobility (supporting S-D logic pillars, multidisciplinary dimensions and supporting methods)

The *social* and *urban* dimensions reflect the view of the city as a service system and focus on the integration of stakeholders that are connected in *actor-to-actor networks* where many-to-many interactions occur. To improve the integration of stakeholders in a network perspective, service design methods such as SD4VN can be adapted to the urban context. The intersection of *social* and *technological* dimensions relates to the digitalization of social interaction that already exist in service domain. Therefore, Multilevel Service Design artifacts can be adapted to our context.

The intersection of *organizational* and *technological* dimensions can be studied by enterprise architecture methods. For this purpose, we have chosen the Enterprise Architecture Design method since it focuses both on process management (*organizational* dimension) and on the support provided by Information Systems (*technological* dimension). Finally, the Zachman Framework provides the holistic vision of the city as an enterprise, stressing the organizational issues of the urban context, thus responding to the intersection of the *urban* and *organizational* dimensions.

The next sections detail how different research domains (as explored in chapter 3) and the methods mentioned in the previous paragraphs (decision-making processes, service design, and information systems) contribute to the proposed multidisciplinary approach to urban mobility approach.

4.1.1 Decision-making

The study of decision-making processes in this work aims mainly at understanding how decisions are structured and made. If the goal is to improve both the design of new urban mobility policies and the usage of the transportation system by passengers, we need to influence the way they make decisions, whether it is a complex strategic decision made by the municipality or a transportation operator, or a simple and daily decision made by passengers and residents.

To do so, we need to understand how different stakeholders process the information and what information they need to make a good decision. In practice, real situations can be rather complicated, as most of the decisions we make daily have an intrinsic multi-criteria nature. Furthermore, the outcome of the decisions is strongly dependent of the information we have within our reach. That is why improving the access to information is key to improve the quality of many decisions.

Considering the three main stages typically considered in any decision-making process (data collection, data analysis, and analysis of results), in this multidisciplinary approach we propose that before collecting data, an inverse approach should complement these stages by questioning what the decision will be and what information is necessary to support that specific decision (Figure 4.2).

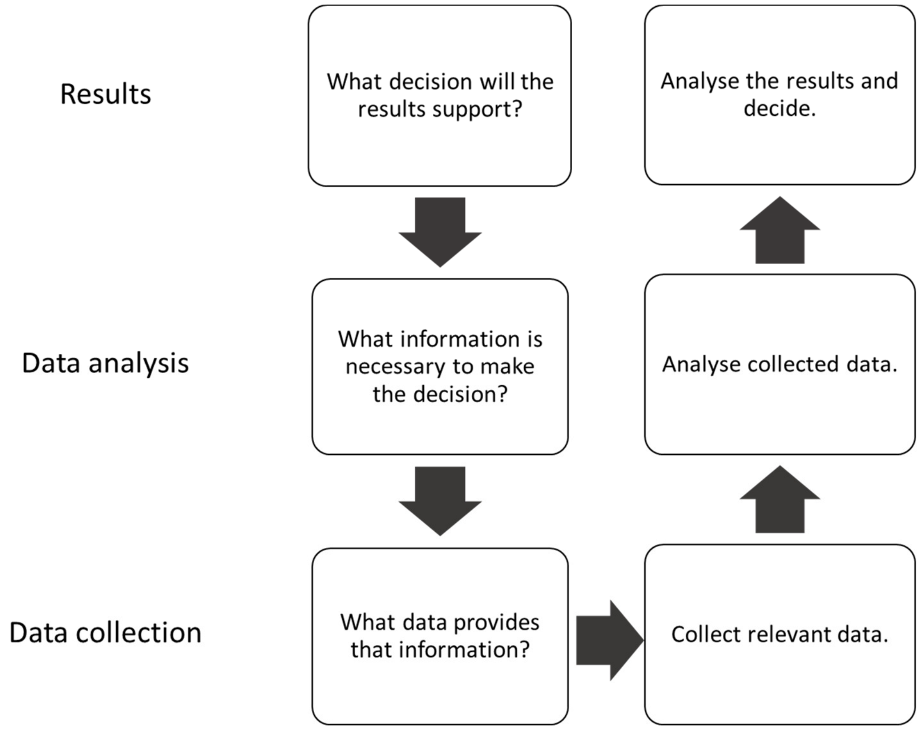

Figure 4.2. Complementary questions to decision-making.

Although they may need different information to make their decisions, stakeholders sometimes have information that can benefit other stakeholders. Hence, increasing co-creation may significantly improve decision-making and benefit all stakeholders' groups, and the city as a whole.

EXAMPLES

Municipalities have information regarding urban policies and regulations that citizens and transport operators need.

Citizens, as users of the transport system, are more prone to detect problems and may help municipality in understanding the current urban situation.

Transport operators have data about their operations that are useful for citizens as users, and for municipalities as managers of the infrastructure.

4.1.2 INFORMATION SYSTEMS

Management Information Systems (MIS) have been used to improve the efficiency of companies for a few decades, and with those systems, process reengineering became an important part of quality improvement in many businesses. This use spread out to different areas of the public sector such as health, education, and municipalities. However, urban mobility involves many stakeholders, and it is common for each of these stakeholders to have its own information systems (IS). For example, the municipality has a specific IS to support their processes management, the public transportation operators have another IS to support their network and operations management, and other possible mobility services also have independent IS. This causes each stakeholder to manage his part of the transportation network independently, hindering the existence of a single multimodal network.

If we want to move towards a multimodal transportation network, it should be viewed and managed as a single entity. Again, to do so, all stakeholders need to be included in the decision processes and collaborate actively. Such integration can be achieved by an information system (IS) capable of responding to different types of decisions and considering their different needs.

EXAMPLE

Municipalities manage the road network infrastructure where public transport operators provide their services.

Public transport operators manage operations that use the infrastructure managed by the municipality.

Municipalities and public transport operators need to easily share information so that they can perform their tasks efficiently.

Moreover, the lack of integration of urban planning and urban mobility leads urban and mobility planners to design urban policies that do not have a holistic perspective and sometimes do not consider the mutual impacts of land use and mobility.

EXAMPLE

The solution for less congestion may not be in a road or in a new bus line, but in bringing services, parks, and other equipment closer to residential areas.

This integrated approach would allow the collaboration between multiple stakeholders not only by accessing information, but by providing relevant information to others. In this way, public consultation processes would also benefit from the knowledge co-creation capabilities of the IS.

Considering now the *technological* dimension, the fact that different stakeholders use different data structures also creates barriers for a better understanding and management of urban mobility. Throughout their course of existence, systems are updated or exchanged, yielding an accumulation of heterogeneous data with conflicting syntaxes or ambiguous information. Different systems may represent data of the same nature with their own terminology, causing misunderstandings when trying to interact with other actors. The lack of interoperability across systems may cause data to be isolated and analysed in data silos, which may lead to short-sighted interpretations about urban mobility phenomena.

Several features of the Zachman Framework (Zachman 2011) are useful in a complex context as urban mobility. Namely, this framework includes multiple perspectives (planner, owner, designer, builder, implementer, operator), allowing for the integration of different stakeholders in the design process, based on asking simple questions that are helpful and can be adapted to our context (*what, how, where, who, when, why*). Moreover, the holistic view of the Zachman Framework helps to maintain a holistic view of the city.

The Enterprise Architecture Design (EAD) proposed by Velho (2004) has the advantage of being focused on the redesign of an existing system, while redesigning business processes, which is one of the goals of our approach. EAD is built on inputs from different IS frameworks, making it a very complete method and a natural inspiration for our work.

4.1.3 SERVICE DESIGN

The inclusion, in this work, of Service Science, through service design methods, is justified by the fact that service design approaches have the potential to reshape mental models, as they promote the understanding of how actors' perceptions and actions change existing institutional arrangements that are critical to the way value is co-created (Vink et al., 2019). Combining ideas present in the concept of *smart sustainable cities* with the idea of *city as a service system* as proposed by Polese et al. (2019) can help in implementing an S-D logic in the context of urban mobility.

Methods as Multilevel Service Design (MSD) and Service Design for Value Networks (SD4VN) show the potential success of co-creation for designing new services in complex contexts (Patrício et al. 2011, 2018). The higher the level of customer participation in the design process, the higher the success of the new service. Taking this observation to the urban context means that the higher the level of public participation in policy design, the better the acceptance of the new policy.

Nevertheless, in the service sector, customers are expected to continuously have an active voice after the design stage. In the urban context, this means there should be a continuous communication between service provider and customer (the citizen). So, implementing an S-D logic in the urban context will require rethinking participation processes in order to foster co-creation and develop a collaborative and participative environment.

EXAMPLE

A transport operator that manages has an efficient network system (sticking to the schedules, with short waiting times, etc.) but has a bad customer support (passengers have difficulties in paying their monthly fees, late responses to problems, etc.), ends up providing a bad service experience.

4.2 A CONCEPTUAL FRAMEWORK FOR DESIGNING AN INTEGRATED INFORMATION SYSTEM FOR ENHANCING URBAN MOBILITY.

Inspired by the Zachman Framework, our conceptual framework can be viewed as somehow establishing a comparison between the structure of a building and the development of an integrated information system for urban mobility. The pillars of this multidisciplinary approach provide the support and the dimensions proposed create the structure (Figure 4.3). To complete the structure, the conceptual framework presents five blocks that guide the development of the integrated IS.

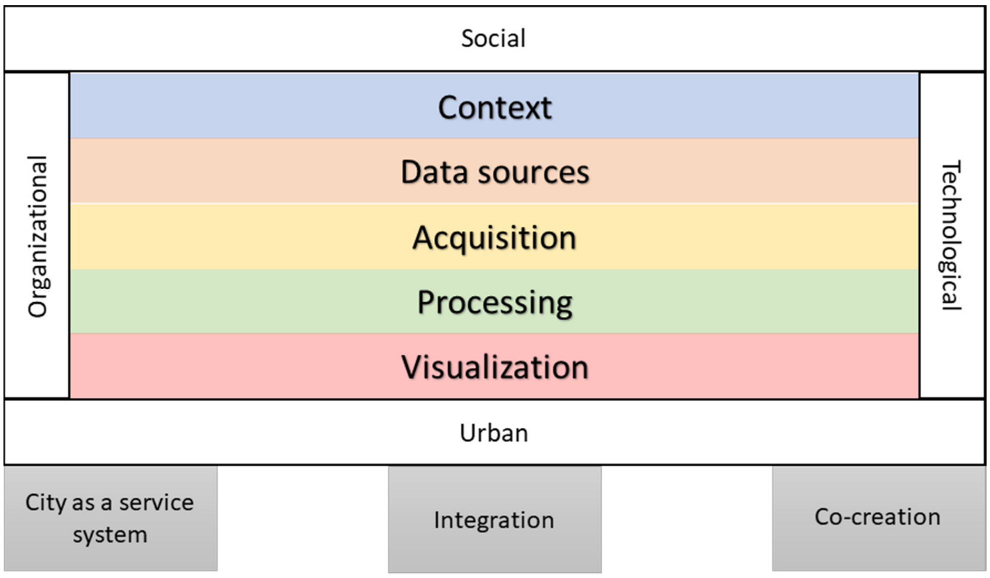

Figure 4.3. Conceptual framework for designing an integrated IS for urban mobility.

The *urban* dimension sets the foundation for our work and is, therefore, considered the first layer of the building (as the foundation slab) that is laid over the pillars.

The *organizational* and *technological* dimensions represent the walls of the building, connecting the *social* and the *urban* dimensions. The organizational structure and the technology available will determine how stakeholders interact in the urban space.

The *social* dimension is laid on top of the building because the IS is designed to support the social interactions through which stakeholders co-create knowledge and value. These interactions cannot take place without the other dimensions.

The proposed blocks (Figure 4.4) follow the decision-making process considered in the previous section (Figure 4.2). The two first blocks (*context* and *data sources*) relate to the questions proposed in our approach:

1. What decision will the results support?
2. What information is necessary to make the decision?
3. What data provides that information?

These two blocks focus on understanding the stakeholders and the decisions they make, as a way of identifying the necessary data and then detail how that data can be obtained. The *data sources* block also includes a description of the data architecture of the IS.

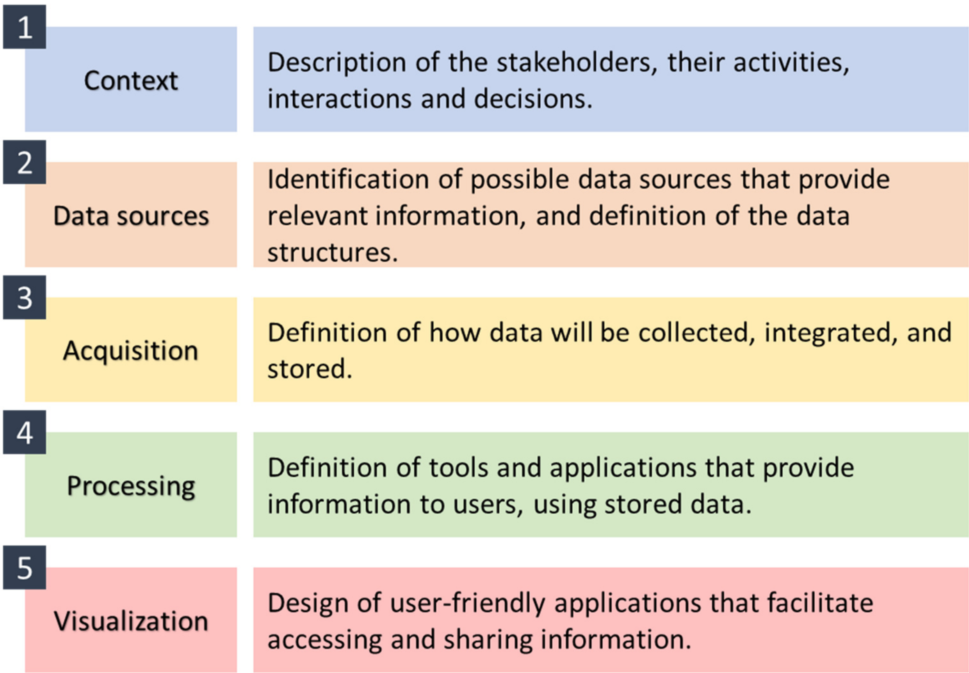

Figure 4.4. Building blocks of the conceptual framework.

The *acquisition* and *processing* blocks describe the technological requirements, corresponding to the application and technological architectures from the EAD method. The *visualization* block details, for each stakeholder, the interaction with the IS, and is related to the design of the service encounter that can be achieved using the service experience blueprint. The five blocks, developed with an S-D logic, fit into the Zachman Framework (Figure 4.5), hence contributing to the application of a S-D logic to the design of an integrated IS. The next sections further detail each of these blocks.

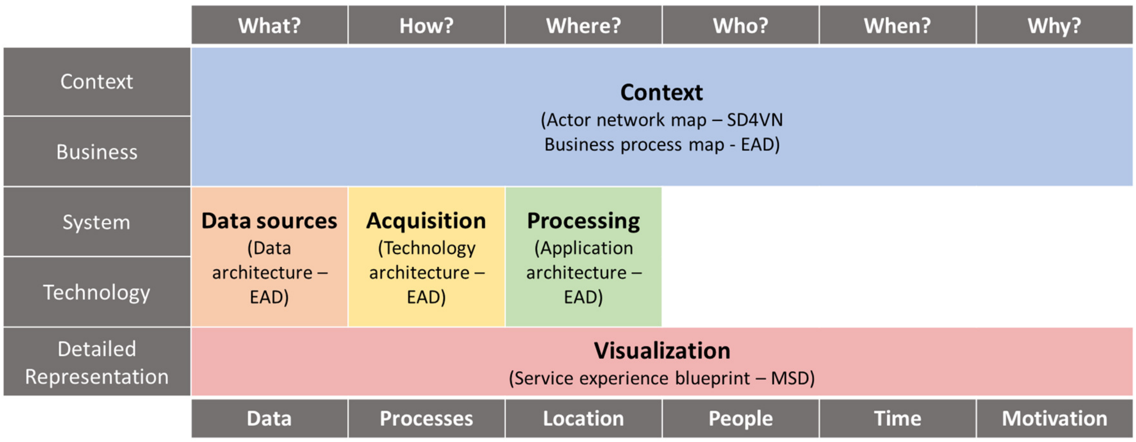

Figure 4.5. Relation of the proposed framework to the Zachman Framework.

4.2.1 Context

As suggested by the frameworks presented in chapter 3, the *context* block includes the definition of the goals and purpose of the system. Due to the existence of multiple stakeholders, these goals must be determined by the users of the system, as long as they respect the main goal defined by the three pillars of the framework. To address this issue, we consider the suggestion made by Velho in the Enterprise Architecture Design, when he presents the *strategic-operational summary* (Figure 3.12) that includes mission, values, and goals for an enterprise.

Since we are in a multistakeholder context, we need to analyse the goals of the different groups and understand their motivations and needs. The Service Design for Value Networks (SD4VN) proposes an *actor network map* that can be adopted in our context, as well. A map of stakeholders is useful to understand the context and the relations and influences between the stakeholders. For instance, the citizens' behavior influences the operators' supply, and the existing supply influences the citizens' choice of using or not using public transportation.

By understanding the network of stakeholders and the links between them, it is in general possible to infer what information they need. Nonetheless, stakeholders should also be able to state what information they wish to access.

Another possible approach is the usage of business process maps as proposed in the Enterprise Architecture Design, during the description of the *business architecture* (Figure 3.12). Business process maps are useful in modelling the decision-making processes of a specific stakeholder, helping to describe the activities that lead to the decision, and to identify the information required during the process.

EXAMPLE

A local business regularly needs freight to be delivered at their store. Considering the activities associated with scheduling the delivery, the company needs to have information about loading/unloading bays (information provided by the municipality), information about schedules and duration of operation (information given by the logistic service provider). If there are no unloading bays and the operation causes congestion, the municipality may need to know how the operation will impact traffic in the area.

The specification of the system requirements is also important to ensure that the goals and purpose of the system are met. Within the *context* block, requirements can be built upon the previously mentioned artifacts. For instance, the *strategic-operational summary* helps define requirements related, for example, to business rules and administrative functions. The actor network and business process maps help define requirements related to authorization levels, the relationships and potential interactions between stakeholders, and the interfaces that will be manipulated by the stakeholders throughout decision processes and service touchpoints.

4.2.2 DATA SOURCES

The *data sources* block aims at determining the data that needs to be collected, and at defining the data architecture. To avoid collecting irrelevant data, the information retrieved in the *context* block can be used to identify what data is necessary, and one or more data sources that need to be considered.

This information can be structured using *decision matrices* (Figure 4.6), that were inspired by the Zachman Framework. The cells of these matrices contain the information that stakeholders consider relevant to support their decisions. Decision matrices can be as detailed as necessary for the specific project under consideration. For instance, they can be organized by stakeholder and by level of management.

EXAMPLE
Passengers want to know the real time of arrival of a bus at a given stop and use that information to plan their trips.
Public transport operators use the real time of arrival to infer the delays and might use that information to redefine headways of one or more lines.

Finally, based on the information requirements raised, it is possible to identify the data to be collected. Some data cannot be obtained directly; so, some indirect ways to do it should be considered at this stage.

EXAMPLE
Real time of arrival can be based on automatic vehicle location (AVL) data. However, in the case of AVL failure, this system might compare the time stamp of the passengers using that bus line.

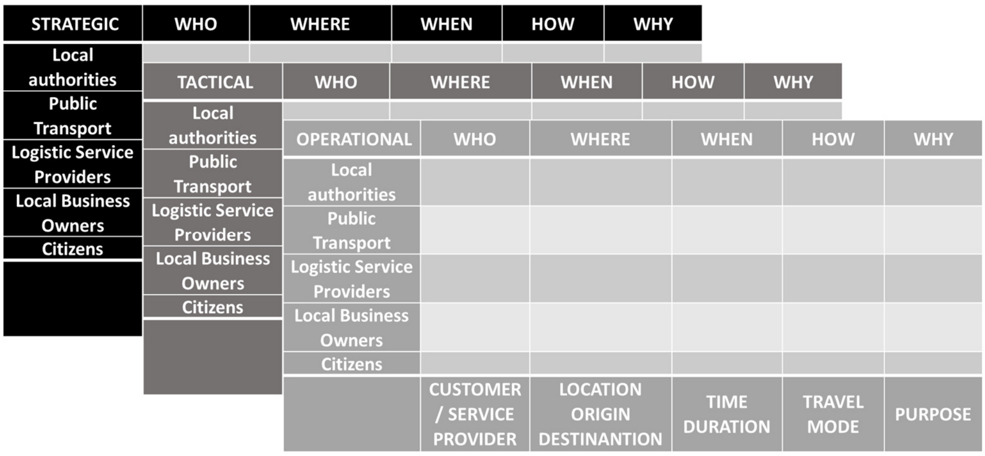

Figure 4.6. Decision matrices.

Common sources of quantitative data in the urban mobility context may be expensive and may require specific hardware difficult to deploy. However, the current availability of mobile devices and the easy access to the internet allow people to be connected at any time and everywhere. Local authorities can strongly benefit from having access to large amounts of data and from retrieving useful information created by those services. For instance, citizens can feed the system with data about traffic, that will be provided to other citizens, but that data can also be used to create knowledge regarding the current situation of urban mobility for local authorities, when designing new urban mobility policies. Moreover, different types of data can be provided by local authorities to inform citizens (e.g., construction sites, parking availability, bus schedules, etc.). This suggests that most of the required data is available but spread across different stakeholders.

The idea that collective knowledge can help solve problems is not new, but Web 2.0 technologies brought new opportunities in this direction, since they made the Internet a collaborative and participatory environment (Bizjak, Klinc, and Turk 2017). The concept of *crowdsourcing* is based on this idea of open communication, where people cannot only consume information but also provide information to others.

Therefore, considering stakeholders as a source of qualitative data can help in easily detecting problems, without high investments in hardware, and, at the same time, in assessing the perceived quality of the system, i.e., in getting information on the citizen experience.

EXAMPLE

Passengers can generate real-time information about transport schedules in rural areas, using an ad hoc *crowdsourcing* mobile application, to account for situations in which a transport fleet may be unprovided of AVL systems.

4.2.3 ACQUISITION

The *acquisition* block aims at defining how data will be collected, integrated, and stored. This block relates to the data architecture of the EAD. As such, it should describe entities, classes, and the relations between them, and how all data will be stored.

According to the EAD, a relationship between entities and businesses processes of the enterprise should be established. In our context, we propose to create a relationship between entities and the abstractions of the Zachman Framework, as done in the *data sources* block. For instance, the abstraction *where* suggests location. The questions asked by the different stakeholders in the decision-matrices will indirectly suggest the entities of the system.

EXAMPLE

A person looking for an outdoor space may ask *"Where are the city parks?"*. This question defines the information required, and indirectly suggests one entity of the system will be *"parks"*.

Due to the different types of data retrieved from heterogeneous sources, data integration is needed, possibly by using Semantic Web technologies. In the above example, the concept of a "park", or more generally a "point of interest" may not be explicitly defined in one or more data repositories. It is, however, expected that data that share the same semantics, i.e., the same meaning, are stored according to a knowledge representation model agreed upon by all the stakeholders that are going to interact with the system.

For instance, domain ontologies, such as the Visualization-oriented Urban Mobility Ontology (VUMO) proposed by Sobral, Galvão, and Borges (2020), provide a foundation for the development of knowledge-assisted tools for data generated by Intelligent Transport Systems.

Contexts in which the use of ontologies is not technically possible, e.g., due to technical or human resource limitations, can adopt other data integration strategies. For instance, database schema integration methods can resolve the heterogeneity of tables scattered across various relational database management systems (RDBMS).

Developers and project managers should keep in mind that the IS is expected to provide information based on updated, possibly real-time information, and these data are to be collected over time. Moreover, data can be quantitative but also qualitative. As previously mentioned (*data sources* block), qualitative data can be provided by the stakeholders, as a way to improve collaboration and knowledge co-creation.

4.2.4 PROCESSING

In a complex mobility system, different stakeholders may use the same data for quite different purposes. At the same time, there must be different levels of access and permissions for those stakeholders. This will lead to the development of multiple applications, according to their specific needs. For instance, mobile applications can be attractive to citizens, but desktop applications will be required by stakeholders in management positions.

EXAMPLE

A citizen may only need to consult information and report problems and can do it through a mobile application.

Customer support staff will require a web or desktop applications at the workplace.

The design of the applications should consider the pillars of the framework, mainly *co-creation* and *integration*. Therefore, they must bring stakeholders closer, facilitating the exchange of information and developing a collaborative environment in the community.

To respond to the digitalization challenges, four main potential solutions based on Web 2.0 technologies were identified: chat rooms and messaging solutions; web forums; social networks; and mobile applications (Table 4.1). These solutions present different characteristics regarding the number of participants, type of interaction, and response time. We considered these characteristics to be those that have the highest impact on the user experience.

Direct interactions occur when a customer interacts with the service provider staff; and indirect interactions occur when a customer interacts with a digital interface, or if the interaction occurs through an intermediary stakeholder. For instance, using a municipality's website is an indirect interaction as it influences the experience regarding the municipality, but it does not require any action from the municipality staff.

Table 4.1. Interaction tools and their characteristics.

Tool	**Type of interaction**	**Participants**	**Moment**
Chat rooms and messaging	Direct	One-on-one	Instantaneous
Social networks	Direct and indirect	Community	Continuous
Web forums	Direct	Community	Continuous
Mobile applications	Indirect	Community	Continuous

MAIN ADVANTAGES

Chat Rooms and Messaging. Messaging tools may bring authorities closer to citizens, and a proper management of the responses can improve the trust and the image of authorities amongst citizens.

Social Networks. Social networking creates opportunities for citizens to interact with each other and with the local authorities. It reduces the effort from the municipality to read and answer all the incoming requests for information.

Web Forums. Using web forums has some of the advantages of social networks and chats. However, one weakness of forums is that, in general, they are not as in-real time as the others tools.

Mobile Applications. The possibility of using a mobile application to create and consume information may be the most interesting option for local authorities. In a collaborative context, citizens can register their experience and share difficulties about traffic, parking, etc. Data provided by the city can be updated with citizens' input, and made available in real-time.

Currently, many platforms allow for vertical or horizontal communication. Mobile apps, such as Waze and Google maps, provide information about traffic, and some cities have developed dashboards that make that information available to citizens.

When designing the applications, the project leaders must select one of two options. Either all the applications are built as part of one single system, or third-party applications can be integrated into the system. This second option has the advantage of easily attracting users from other applications (e.g., social networks, GPS services, etc.); but on the other hand, it requires a seamless interface between the different applications.

Based on these principles, the *processing* block focuses on defining the applications where data will be processed and made available to users. As proposed by the application architecture of the EAD, this block must not only include the list of the applications, but also their description. In our context, instead of relating processes and applications, we rather need to describe the relationship between the applications and the services, thus combining the EAD with the Service Architecture proposed by the Multilevel Service Design.

4.2.5 VISUALIZATION

The *visualization* block is related to the moment when information is made visible to users. In technology-based services that interaction occurs through digital interfaces; and developers need to identify those moments in order to assure a good user experience. For this reason, this block includes the design of the layout of the displayed information, using human-computer interaction techniques, and the design of the workflow during service encounter, using service design methods, such as the *service experience blueprint* (SEB).

As exposed in chapter 3, SEB supports the design of the process and the identification of the possible moments of delay or failed service. Since SEB also presents front-end and back-end tasks, it is possible to identify moments of direct and indirect interactions, and consequently identify the interfaces that will be designed.

In an effort to keep the focus on the user of the system, some adaptations of the originally proposed notation have been made (Figure 4.7 a and b). Considering the multi stakeholder context of the city, the first row of the SEB does not need to be the customer (citizen) since there will be processes where citizens do not participate. Hence, in each process, we propose the first row is assigned to the main stakeholder of the process.

Moreover, adding to the front-end/back-end (or frontstage/backstage) and the lines of visibility, we propose a clear identification is made of the moments when an interface must be designed (Figure 4.7 c).

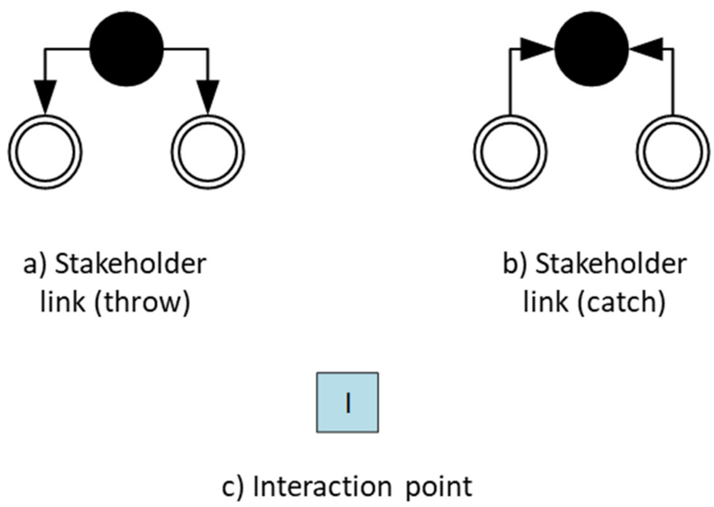

Figure 4.7. Additional notation adopted for SEB.

The *stakeholder link* will be used when the main stakeholder of the process is not the same in two sequential processes. It works in a similar way to the *interface link*. The interaction point is used to mark tasks represented in the SEB process diagram that need further detail through human computer interaction techniques to design the interface of the application. It can be used as the *fail point* of the *waiting point*.

EXAMPLE

Here we describe a situation from the second case study described later, in chapter 5.

A citizen has got, by mail, a fine for not having paid a trip. As, for some reason, he does not agree with this penalty, he goes to a Loja Andante (service desk). There he interacts with the service assistant, who will use the information system to register the case. Later, the citizen receives a response from the transport operator, informing him that they are not responsible for processing the fines, and they will forward the case to another entity.

Here, we have 4 stakeholders (citizen, service assistant, backend support of entity 1, and backend support of entity 2). Each of these stakeholders will interact with the system at different moments, but for the citizen there is only one interaction with the service provider.

We use the *stakeholder link* to connect these processes and highlight the change of main stakeholder in the process. By doing so, we improve both the tasks performed by the citizen and by the three service providers.

The *interface link* is used when the stakeholder is the same, but there is a change in the channel of interaction (e.g., the process starts at the service desk but the citizen receives notifications by e-mail).

4.3 SUMMARY

A multidisciplinary approach to urban mobility is essential to understand the complexity of cities and to improve the quality of the decisions made by the different stakeholders. Applying an S-D logic through the adoption of an integrated information system will foster an easy access to information that will lead to better decisions.

This multidisciplinary approach, proposed in section 4.1, is based on a holistic view of the city as a service system in a socio-technical transition period. For that reason, it encompasses the study of *social*, *urban*, *technological* and *organizational* dimensions of the urban mobility context.

The approach, based on the integration of these dimensions, is expected to positively impact the city and its transportation system, and it involves mobility and land use, stakeholders, information, and strategic, tactical and operational decisions. It was materialized in a conceptual framework for designing an integrated information system that focuses on the needs of multiple stakeholders and on improving the communication between those stakeholders.

The framework is composed by five building blocks (*context, data sources, acquisition, processing,* and *visualization*) that are supported by the three pillars (*city as a service system, integration,* and *co-creation*) and framed by the four dimensions (*urban, social, technological,* and *organizational*) of the multidisciplinary approach. The five blocks were developed to apply an S-D logic in the design of an integrated IS in an urban mobility context.

Table 4.2 summarizes the methods and artifacts considered in the framework.

Table 4.2. Methods and artifacts considered in the framework.

Framework's blocks	Proposed artifacts	Background methods
Context	Business process maps Strategic-operational summary	Enterprise Architecture Design
	Actor network map	Service Design for Value Networks
Data sources	Decision matrices*	Zachman Framework*
Acquisition	Relationship abstractions - entities	Enterprise Architecture Design
Processing	Relationship process / application	Enterprise Architecture Design
Visualization	Service Experience Blueprint	Multilevel Service Design

* The decision matrices use the Zachman Framework as an inspiration, but are a contribution of our work.

The multidisciplinary approach and the framework we have developed in this research provide an adequate mindset and tools to tackle different cases of service redesign in the urban context. The next chapter of this thesis presents several examples on how the framework can be used in different situations. In an iterative research design process, the lessons learned from those cases are used in chapter 6 to complete the framework, with general guidelines for improving participation.

5

APPLYING THE FRAMEWORK TO INTEGRATED INFORMATION SYSTEMS FOR URBAN MOBILITY

5.1 INTRODUCTION

This chapter presents a set of illustrative cases that were used to validate and assess the framework developed in this research. Each case presents different perspectives of the urban mobility context, yet keeping a holistic view that considers the pillars, dimensions and blocks presented in the framework. The application of the framework to these cases helped validating and refining the framework and contributed to the development of the guidelines presented in the next chapter.

As suggested by the Design Science Research guidelines, the illustrative cases serve as descriptive scenarios commonly used in the validation of artifacts as frameworks. According to Peffers et al. (2012) descriptive scenarios are an *"application of an artifact to a synthetic or real-world situation aimed at illustrating suitability or utility of the artifact."*; and (Hevner et al. 2004) state that descriptive scenarios *"construct detailed scenarios around the artifact to demonstrate its utility"*.

To build the cases, contributions from experts were gathered and used to adjust the cases to real life situations. Moreover, those contributions helped in identifying the groups of stakeholders that play a role in the urban mobility context.

5.1.1 IDENTIFICATION OF STAKEHOLDERS GROUPS

The roles of the different stakeholders within the urban context differ, and therefore it is crucial to understand who they are and what is their typical behaviour. Based on the literature, a map of stakeholders was built, validated, and completed by experts (Figure 5.1). Considering the idea of *the city as a service*, both the urban services and the urban planners are considered as the service providers, as a way to highlight the fact that they should work as partners to serve citizens. Besides the groups of stakeholders, the map presents different profiles in each group. These *sub-groups* were based on the similarities regarding the use of the transportation network.

At a macro level (top part of the figure), we consider both *urban* and *mobility planners*, representing the most strategical decisions about the city and the transportation network (this is the *service providers* group). At the intermediate level, there are *urban services* (for passengers or freight, or even for maintenance and utilities) that operate according to regulations defined by the planners. These two groups make decisions that impact the offer and the quality of the transportation systems.

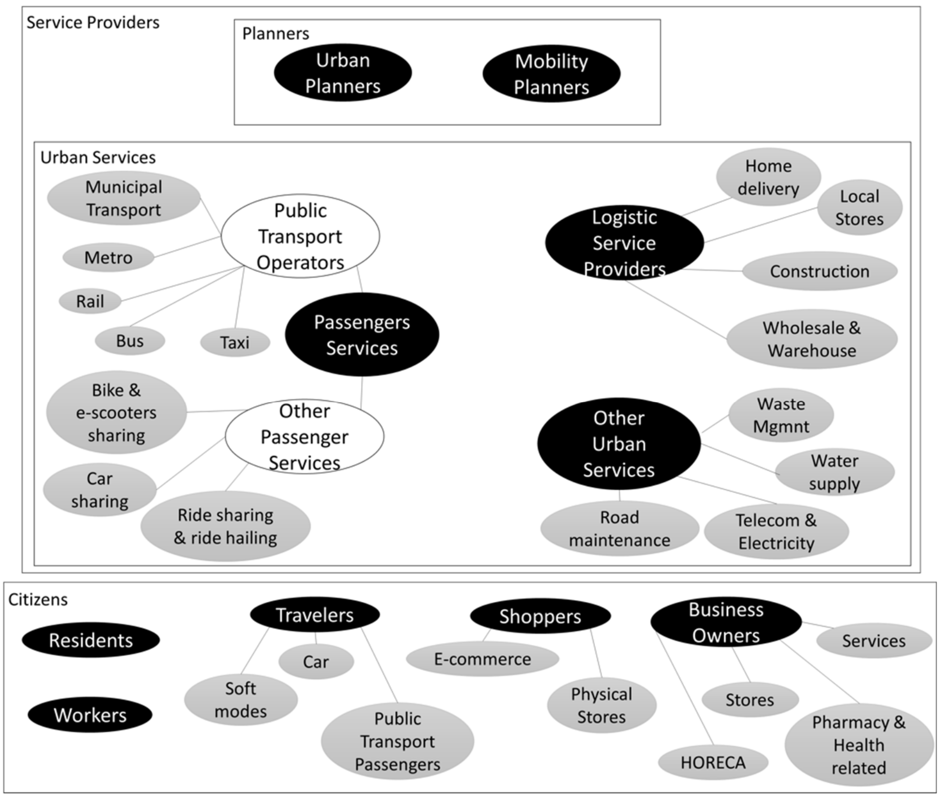

Figure 5.1. Urban stakeholders map.

The *citizens* group includes several profiles of citizens according to their roles. Citizens make decisions on the demand side, and these decisions will depend on the service offer available, and the choices of this group can obviously influence future decisions of the service providers.

For the sake of simplicity, the interactions of these profiles were not represented in the map, as they all may interact with each other at different times. Some of these interactions are explored in the illustrative cases.

URBAN AND MOBILITY PLANNERS

Urban and mobility planners are considered here as part of the *service providers* group because their decisions will directly influence the routes that other service providers can use. Moreover, by developing urban and mobility plans aiming to improve citizens' quality of life, they are providing a service to the citizens.

The way the municipality admitnistration is organized directly influences how urban and mobility planners work. Some cities assign these functions to different departments, while other cities create subdivisions within the same department, thus facilitating an integrated approach in designing the urban space. Organizational structure is mostly a political choice and may influence policy design.

The activities of this group are related to policy and regulations, or with infrastructure. Regarding policy and regulations, the EU recently introduced the concept of Sustainable Urban Mobility Plan (SUMP), so that mobility and transportation could be explicitly included in the urban planning process. Moreover, new policies related to city logistics are being developed following the Sustainable Urban Logistics Plan (SULP) guidelines. A SULP is part of a SUMP and focuses on logistics activities. This fact highlights the importance of having regulations for all transportation activities within the city.

The *service providers* group is responsible for the strategic decisions related to land use and infrastructure development, or limited traffic zones and road network design problems, thus impacting the supply capacity for urban mobility. The design of new urban policies requires a good knowledge and a diagnosis of the city, considering environment, economics, demography, etc. Hence, urban and mobility planners benefit from increasing their knowledge on the relationships citizens establish with the city.

PUBLIC TRANSPORTATION OPERATORS

As mentioned in chapter 2, Urban Transport Network Design Problems (UTNDP) includes the Public Transit Network Design and Scheduling Problem (PTNDSP) that is divided into several sub-problems at the strategic and tactical levels. These strategic problems are tackled by Public Transport Operators, who also have operational problems in managing daily tasks, such as vehicle and crew scheduling.

Transportation operators can strongly benefit from the collaborative environment created by an integrated information system, since they will be able to access more accurate information about population sociodemographic profiles and citizens' behaviours, as well as updated transportation regulations and policies. However, to fully benefit from the collaboration, operators should be willing to share their information, but as it is well-known, information sharing can often be quite difficult and challenging.

LOGISTIC SERVICE PROVIDERS (CARRIERS)

Freight carriers are mostly concerned about efficiently managing their transportation operations. Freight related problems mainly handle the choice of routes, service frequencies, and location (e.g, collection kiosks, urban consolidation centres, etc.). As in the previous group, information sharing can result in significant advantages but is, in practice, quite challenging.

Another advantage carriers have in working as partners of the city planners is that they can participate in the policy design process, thus achieving policies that are more suitable for their operations. This collaboration can naturally emerge from the implementation of the SULP methodological approach. In this context, a participatory, bottom-up approach starts with users' needs, service providers' operational requirements, and cities' objectives (ELTIS n.d.). The requirements regarding network usage and parking will vary, depending on the delivery size and product type.

OTHER PASSENGER SERVICES

This group includes the new services that have been emerging with the growth of the sharing economy and the mobile technologies. They are here considered together, because they are services that are still to be regulated by many cities. However, these services may have quite different impacts on cities since the different types of vehicles (bicycles, scooters, cars, etc.) these business models consider have different impacts on congestion.

For instance, while a ride-hailing service using private cars does not remove cars from the street and occupies residents parking places, a bike sharing service has a low street occupancy, but uses sidewalk space to install docking stations.

These services are dependent on city policies and on the local easiness of business access. The success of an e-scooter or bicycle sharing service strongly depends on the easiness of cycling and the safety bikers feel while using those services. Some cities might impose parking restrictions on these vehicles, forcing business models to be adapted or some companies to leave. Moreover, having cars, buses and soft modes sharing the same space in streets will often cause a rising level of complaints among vehicle drivers and citizens in general.

In what concerns ride-sharing and ride-hailing services with private cars, their impact on traffic is still unknown. But some municipalities believe they are responsible for an increase in congestion and problems in parking.

Due to the rapid growth of these new services, urban and mobility planners should be prepared to develop new regulations that explicitly include these services and that are flexible enough to accommodate other new, emerging ones. On the other hand, service providers need support in understanding existing regulations, when designing their businesses. In this case, service providers and mobility planners need to work together to better serve citizens.

Most currently available services are already based on mobile applications and GPS location. Nevertheless, users of such services could benefit from planning multimodal trips. To do so, their information should be integrated into the same IS.

OTHER URBAN SERVICES

These services include utilities and waste management, and even if they do not directly relate to transportation, they are crucial to the daily city life. The impact of waste management on congestion is similar to the one caused by logistic service providers.

Regarding the maintenance of utilities, workers need to access manholes, thus causing some streets to be closed for more substantial periods of time. Although their activities are not frequent, they can produce high impacts on congestion.

These services can provide information about their operations, so that citizens can adjust their routes, and carriers can plan their deliveries accordingly.

Citizens

This group of stakeholders includes the people in the urban area that use the transportation system. They can be travellers in the public transportation network, car drivers, bikers, or walkers. But they can also be shoppers, workers, or business owners, i.e., anyone who has an interest in the efficiency of the transportation network. For example:

- a local store will influence the transportation system when negotiating the delivery processes with the suppliers or logistics operators;
- a resident will wish the neighbourhood to have some walkability characteristics;
- an e-commerce customer will need to access pick-up points;
- a logistics operator needs to access parking spots near the delivery address;
- and local workers wish to have good public transportation or good parking places.

The members of this group can adopt different behaviours depending on their role when deciding. The same person will make a different choice when travelling for leisure or work. For instance, when traveling for work, people (i.e., commuters) tend to choose the same path and have fixed schedules; thus, they might use public transportation if schedules are convenient and reliable. But when going shopping, they will possibly choose driving their car since they need to carry bags, with parking availability becoming therefore rather important. On the other hand, ride-hailing services may be more attractive when going out to a restaurant as people value a door-to-door service and do not want to worry about having to look for parking and paying it.

For this reason, multimodal information can support decision-making, by providing transparency about the performance of the different modes and solutions, and by allowing people to plan their trips better.

Typical decisions of this group of stakeholders are related to trip planning, namely whether they use public transport services or their own vehicles. Providing citizens with information about schedules, routes, traffic, and delays can, therefore, be quite valuable. Moreover, allowing the comparison of several options is obviously desirable (Beutel et al. 2014; Rajapaksha et al. 2017).

Besides, since citizens also represent the users of the transportation system, they can provide information on the efficiency of the network and report problems.

5.1.2 SELECTION OF ILLUSTRATIVE CASES

The cases selected for this work present different perspectives of the urban mobility through the eyes of different stakeholders. Based on the S-D logic principles, the cases consider stakeholders as service providers, partners, and customers whose decisions will create value for the society.

Each case follows a three-phased process that considers the five blocks of the framework. Since there are multiple stakeholders, and to take into account their roles in the urban context, different methods were adopted (Table 5.1).

Table 5.1. Different aspects of the illustrative cases.

Case	Main stakeholder	Decision type	Objectives	Methods used in the context block
1	Citizen	Operational	Improve own life. Reduce negative impacts in the city.	Business process maps
2	Public transport operator	Operational, Tactical	Improve service efficiency and results. Improve passenger satisfaction.	Quantitative data analysis
3	Urban planner	Strategic	Improve urban planning processes. Improve the city.	Focus groups Meetings Business process maps
4	Municipality	Operational, Tactical, Strategic	Improve efficiency in city maintenance. Improve quality of life of citizens.	Interviews

Despite having different perspectives and objectives, the cases show that integrating information and adopting an S-D logic does benefits stakeholders. Moreover, when we want to provide a service to others, value should be created for all the participants. Since these impacts can be immediate or not, the different cases also associate the different stakeholders' perspectives with the different decision levels, thus reflecting the multilevel integration approach of the framework.

In this context, the cases build an argument for an integrated IS whose architecture follows the guidelines of the framework. The next sections present the different illustrative cases.

5.2 CASE 1

In this first case, citizens are the main stakeholder. Citizens adopt different behaviours depending on their role in the system at a given moment, and that will influence the information they require. This case shows how citizens may need information from more than one service provider. They may either access one single system where the information is integrated, or they may have to consult multiple services to get the information they need. The argument for integration in this first case is that when the information is spread throughout multiple systems, it can easily be incomplete and lead to wrong decisions.

Based on some observed situations, we have created a hypothetical scenario from which we draw conclusions regarding the information and channels a citizen should have available in order to make a specific decision.

The process follows three sequential phases: understanding the decision-making process; identifying information requirements; and identifying the interaction moments (Figure 5.2). These phases are directly related to the blocks and dimensions considered in the framework. (Table 5.2).

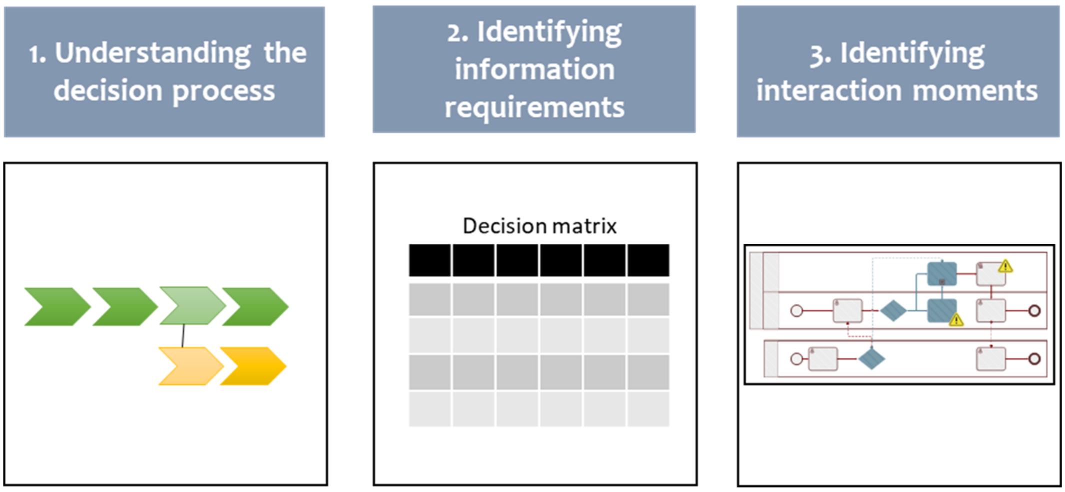

Figure 5.2. Process for case 1.

Table 5.2. The relation between the conceptual framework and the process used in case 1.

Framework	Case 1
Context	Phase 1 – Understanding the decision process
Data sources	
Acquisition	Phase 2 – Identifying information requirements
Processing	
Visualization	Phase 3 – Identifying interaction moments

5.2.1 UNDERSTANDING THE DECISION PROCESS

To understand the workflow that takes place when a citizen is making a decision, we use Business Process Maps (BPM).

In this case, we analyse the example of a citizen planning a trip. Figure 5.3 represents a low detail process map for such decisions. We consider that *home* is the origin of the trip, and that the destination and time of arrival at the end point are previously imposed by a scheduled appointment. Hence, the choice of the transportation mode is the first decision to make. In the case when the person chooses a private vehicle, then he/she will choose the path to follow. If the choice is public transportation, the route will be somehow imposed by the offer in the origin and destination stops.

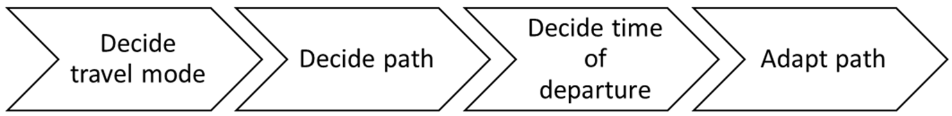

Figure 5.3. Citizen's decision process for planning a trip.

After deciding the transportation mode and the path, it is possible to estimate the duration of the trip and decide what time one must leave home – the time of departure. The process (Figure 5.3) considers that the path may be adjusted during the trip, in the case some obstacles are met (congestion, closed roads, accidents, etc.).

The process map allows us to identify the decision variables considered by the citizen. In this case three decision variables are considered: the travel mode, the path, and the time of departure.

5.2.2 IDENTIFYING INFORMATION REQUIREMENTS

Based on the decision variables and factors identified with the process map, it is possible to fill in the decision matrix (see chapter 4) by assigning variables and factors to the abstractions – *who*, *when*, *where*, *how*, *why*. Figure 5.4 presents the matrix row related to the decisions of the citizens.

	WHO	WHERE	WHEN	HOW	WHY
Citizens	Who can provide me information and where can I find it?	Where I am going to? (Destination) Which is the best path?	How long does it take to get here? What time is less congested?	Which is the better transport? Private or public? Individual or collective?	Why do I need to get there?

Figure 5.4. Decision matrix – citizen's row.

Who relates to the source of information. In a multi-stakeholder environment, the citizen needs to know who can actually provide the information. Although the IS is expected to integrate the required information, the citizen will still need to interact with different stakeholders depending on the information needed. In this case, when searching for the schedules of public transport, the user interacts with the public transport operator, while if searching for information about congestion and parking, he/she will interact with the municipality.

Where corresponds to the information about the location (origin and destination) and the path to follow. The destination of the trip can influence the decision since some locations can offer better parking or better public transport services. Moreover, choosing to use soft modes will depend on the available paths connecting origin and destination. The origin point can also influence the decision since it will affect the available transport offer and the distance.

When includes all the information related to time. This is the case of the time or the interval of the day when the citizen will make the trip or the duration of the trip itself. In our case, the moment of the day is imposed because it is a previously scheduled appointment. However, the time when the citizen is going to start the trip can vary depending on the transportation mode.

How relates to the available transportation modes. This information is highly linked to a specific location because the offer is not the same throughout the city. In a very central place, the offer may include bus, metro, train, private car, taxi or similar, or soft modes. The choice of the mode is also influenced by the cost and the duration of the trip.

Why is the actual motive for the trip. Since, in this case, there is a predetermined time of arrival, the person will most likely prefer a fast trip and some guarantee of arriving at the destination on time. If it were a non-scheduled trip, the behaviour would be different. For the same origin-destination trip, different purposes may lead to different choices. In the end, this choice will depend on the perspective and behaviour of the user. To fulfil our goal, we need to consider all possible scenarios and enable the IS to provide the information for all possible behaviours.

After analysing the case, we are able to identify the information that is required. Since the motive of the trip and the destination are, in our example, already defined, we focus now on the information required for the *how* (mode), *when* (time), and *where* (path). Then, it is possible to identify the sources of data that should feed the IS. Table 5.3 lists the information required for the citizen to make the decision.

Table 5.3. Information to be collected to support the citizen's decision.

How	Stops Parking availability
When	Schedules Number of transfers Congestion (duration of the trip)
Where	Shortest path Accidents Restricted areas (low emission zones) Network changes during events

5.2.3 IDENTIFYING INTERACTION MOMENTS

The business process map also enables identifying when and what type of interactions the citizen will need. The choices taken before the trip can be made with information from multiple devices, but to make choices during the trip, information should be available in mobile devices. If a private vehicle is used and the citizen is driving, information provided during the trip should be permanently visible and not require any action from the driver. On the other hand, in public transport, information can be available in the same platform of the information consulted before the trip. This suggests that multiple channels should be available, so that users can find the same information when they are in different situations.

Another aspect that we can infer from this case is that service interactions at the operational level will be mostly indirect interactions with the service provider, this meaning that if citizens successfully find the information, they do not need a reply from the service provider. This will help in the design of the interfaces and workflows related to the *visualization* block.

As an example, Figure 5.5 and Figure 5.6 show how these moments can be identified in service experience blueprints (see Appendix A for SEB notation). System designers and developers should keep in mind that potential users currently use some features from other services (e.g., Google Maps, Waze, etc.). Therefore, they can improve user experience by incorporating third party applications and redirecting users to those applications, in certain moments of the trip.

Figure 5.5 and Figure 5.6 detail the moment when the person compares two travel modes (in terms of expected cost and duration) using a dashboard provided by the municipality, then selects one of the two modes, and finally starts the journey in a third-party application.

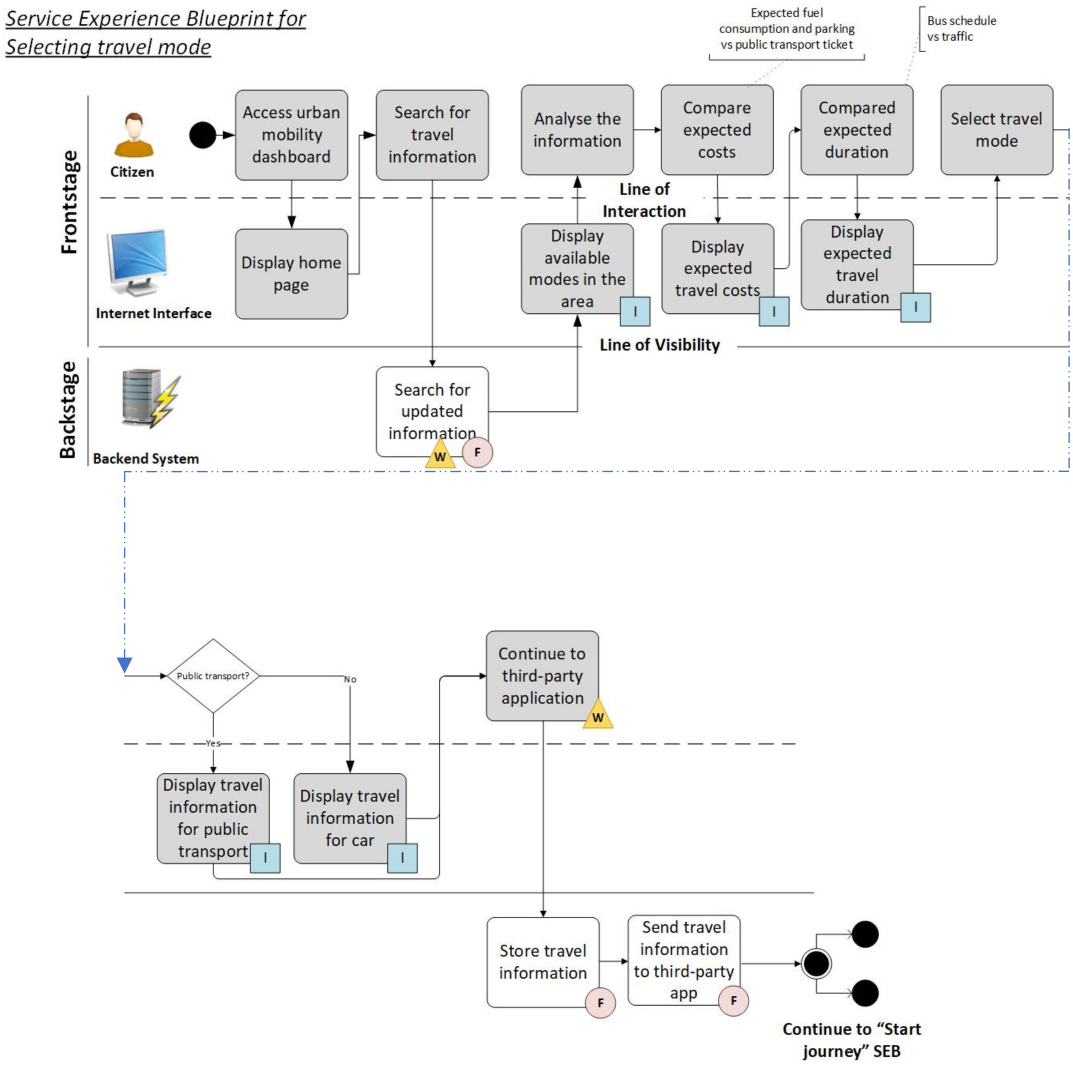

Figure 5.5. Service experience blueprint for selecting travel mode.

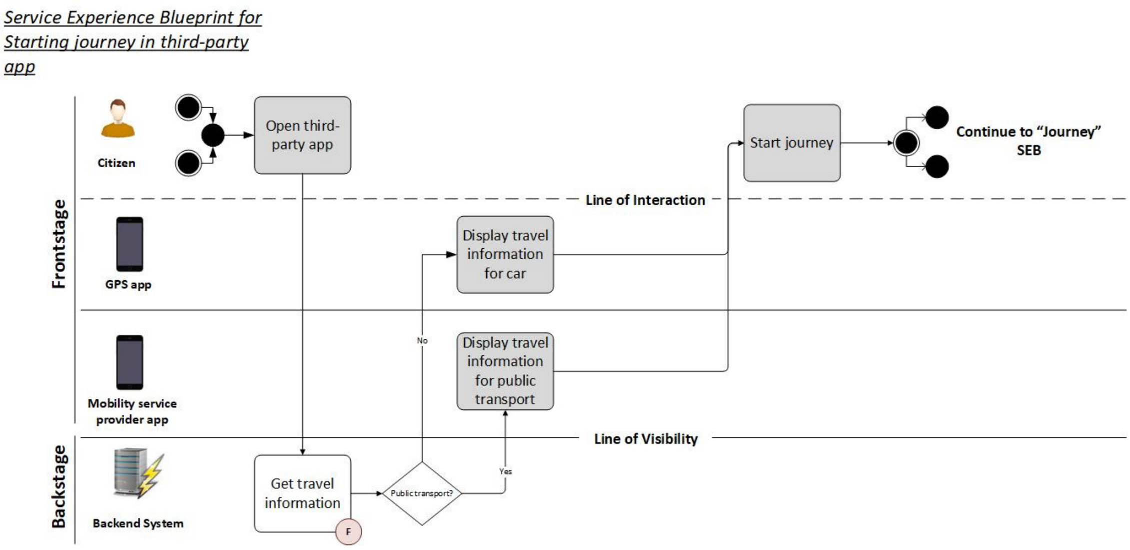

Figure 5.6. Service experience blueprint for starting journey in third-party app.

5.3 CASE 2

In the perspective of public transport operators, mobility services can be improved through co-creation if there are tools that allow for customers to share their experience. If customers are willing to report positive and negative aspects of the service, that information should be considered on maintenance and management plans. These plans are developed to manage priorities in the way problems and suggestions are handled. They include the correction of operational problems such as software problems and infrastructure malfunctions, but also strategic and tactical issues, such as scheduling and accessibility to vehicles (ramps, time of opening/closing doors, etc.).

The contact between customers and the service provider usually occurs through multiple channels centralized in a customer support department. Redesigning processes related to this interaction may benefit both customers and service providers.

An existing mobility service can be improved with data generated by existing helpdesk channels. In this case, we use data from the urban transport operators from Porto, Portugal. This data consists of reports sent by customers (the passengers) concerning the use of a mobile ticketing application called Anda. We use the available reports to analyse the blocks *context* and *data sources,* and to make some considerations regarding the *visualization* block of the framework (Table 5.4). In this second case, the *acquisition* and *processing* blocks were not considered since we were working with historical data to improve the processes of an existing system. Therefore, our goal was not to change the data architecture nor the application architecture.

Table 5.4. The relation between the conceptual framework and the process used in case 2.

Framework	Case 2
Context	Phase 1- Data collection Phase 2- Data analysis
Data sources	
Acquisition	-
Processing	
Visualization	Phase 3 - Process redesign

Instead of analysing all the processes in their current situation, we only select those processes that are expected to benefit from the available data. Thus, before redesigning processes, we collect and analyse existing data (Figure 5.7). Then, the processes selected are redesigned. By analysing the existing cases, we can also create categories according to the content of each report and its urgency.

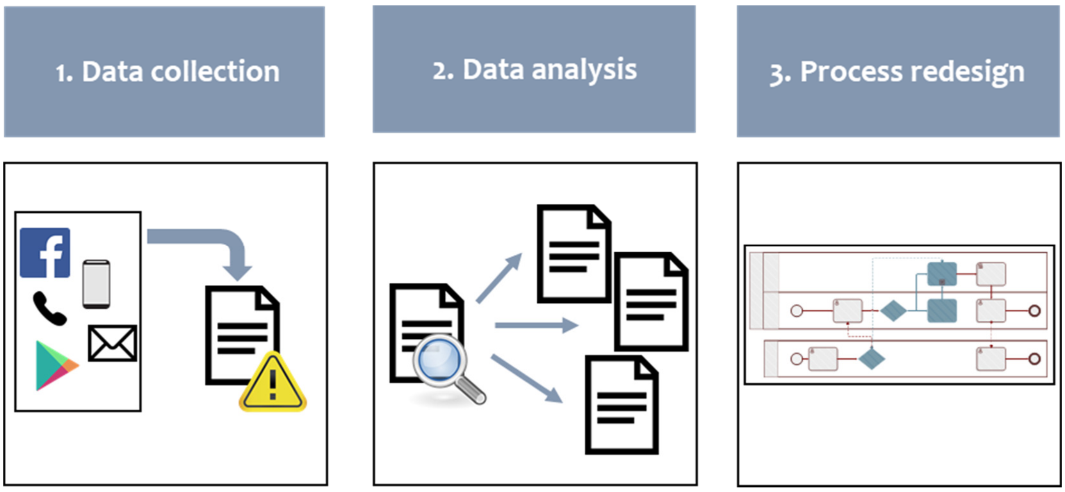

Figure 5.7. Process for case 2.

Since there is a record of reports sent by customers (e.g., complaints, suggestions, and requests), it is possible to identify what processes need to be redesigned. Reports originate support cases and address different issues that will trigger different actions in the back-office, and impact in different ways the maintenance and management plans.

5.3.1 ANDA – A MOBILE TICKETING APPLICATION FOR PUBLIC TRANSPORT

The public transport network of the Metropolitan Area of Porto (AMP) covers an extension of 1,575 km^2, with 1.75 million inhabitants. The system consists of 12 operators covering 157 bus lines (73 public (STCP) and 84 private), 82 light rail stations (Metro do Porto) and 25 train stations (CP – Portuguese Railways). The Andante Intermodal System (SIA), created in 2003, is an important tool to promote intermodality of the public transport system. All 12 operators that are part of SIA have common fare rules and ticketing technology. Passengers may use any of the transport providers with the same ticket regardless of the number of transport operators involved in a trip. The electronic fare system in AMP is open (ungated) and uses an entry-only Automated Fare Collection (AFC) system, based on a distance structure. The fare medium consists of contactless travel cards (Andante), and fares are defined according to a zone structure. To perform a journey, customers must load the travel card with the correct travel ticket for their trip.

Recently, in June 2018, a new fare medium was introduced, which consists of a mobile application called Anda. It is based on a check-in/be-out approach, where the customer intentionally checks-in at a vehicle/station, by tapping the mobile phone on a Near Field Communication (NFC) reader. During the journey, the mobile application is continuously communicating with the Bluetooth Low Energy (BLE) beacons installed inside the buses or at light rail and train stations, allowing for a micro-location of the customer (Ferreira, Dias, and Falcão 2020). When the mobile phone loses the signal of the beacons, it automatically closes the journey. A fare optimization algorithm then calculates the fare to be paid by the customer, which is charged at the end of the month.

The main advantage of the Anda application, when compared to the more traditional Andante travel card, is the fact that customers do not need to have previous knowledge about routes or fares (Ferreira, Dias, and Cunha 2019). Moreover, at the end of the month, customers are charged the minimum possible total value, considering the fare rules in force. However, like any new digital solution, the system still has some bugs and weaknesses, and, from the customers' point-of-view, adapting to a new ticketing media takes time.

Since the full deployment, customers using the Anda application interact daily with the customer support service, through several channels, such as telephone, e-mail, Facebook, Google play, and physical stores. This interaction can have several purposes, such as asking questions, reporting errors, or making suggestions for improvement. The information from the various channels is collected in a single platform, to be further processed and analysed. Depending on the content of the *report*, it can be assigned to the customer support, to a maintenance team, or to the management team. In our case study, *maintenance teams* are the partners of the Anda system that include, among others, the mobile application developers, technical support for the NCF readers and BLE, and the transport operators. The *management team* is responsible for analysing and taking decisions about more complex cases.

The following sections present how the data was used to improve the service, by following the multidisciplinary approach proposed by the framework.

5.3.2 DATA COLLECTION

For this example, we have used data from the reports of Anda customers, from 2019. During this year, a total of 8,624 cases were recorded on the customer support platform. Among other information, these cases include the motive of the report, the channel used, and the type (request, inquiry, or complaint). From all reports, 1,006 had the type and channel as *"undefined"* and were therefore ignored, leaving a total of 7,618 to be analysed (Table 5.5 and Table 5.6). Clearly, the Anda App has become the main channel for reporting.

Table 5.5. Type of report

Complaint	4,919
Inquiry	1,886
Request	813
Total	7,618

Table 5.6. Channel for submitting report

App	3,119
E-mail	569
Phone	1,873
Facebook	58
Google	4
AMT	3
Technical support CMS	20
Flyer	12
Consultation	1,690
Total	7,618

In what concerns the motive of the report, the most common situation is related to the start of the journey (*check-in*) with 2,123 cases, with *redo enroll* (referring to the moment a new user re-installs the application and needs to insert user information for a second time) appearing in the third place, with 1,092 cases (Table 5.7).

Table 5.7. Type of reported cases for ANDA_Redo Enroll and ANDA_Check-in.

Motive	**Type**	**Number of reports**	**Total**
ANDA_Redo enroll	Complaint	674	
ANDA_Redo Enroll	Request	257	
ANDA_Redo Enroll	Consultation	161	1,092
ANDA_Check-in	Complaint	2,034	
ANDA_Check-in	Request	10	
ANDA_Check-in	Consultation	79	2,123

5.3.3 Data analysis

While some complaints may be urgent and need immediate attention (e.g., infrastructure malfunctions), others may need approval to proceed (e.g., reimbursing the price of a ticket); and suggestions will also require analysis and eventual approval. These categories are used during the redesign of the processes and, afterwards, the same categories will help to classify new incoming reports.

By analysing the motives mentioned in the reports, we have identified three main categories:

1. urgent errors;
2. usage and usability problems;
3. and suggestions and not critical or immediate errors.

Urgent errors refer to problems that hinder the operations. They may happen, for example, if a passenger is not able to start a journey when tapping the smartphone, due to a malfunction of the infrastructure. These problems need to be solved as soon as possible, and do not require any approval from management. They should, therefore, be assigned to one of the maintenance teams.

If the journey does not start due to problems with the mobile application, it is necessary to contact the customer, to check if it is possible to solve the problem without the intervention of the maintenance team. This contact is done by the customer support. If the problem requires technical support, the case should be assigned to the maintenance team of the mobile application. Since this type of problems prevent the passenger to travel, these cases should have high priority in the maintenance plan. The situations that can be solved by the passenger with the help of the customer support are included in the category of *usage and usability* problems.

Finally, *suggestions* represent potential improvements to the service, in the passenger's perspective. However, suggestions need to be analysed in order to evaluate their feasibility and implications and can be the basis for further improvements to the service.

These are the categories that have been identified until now. If more categories are identified in newer cases, other processes should be redesigned.

5.3.4 PROCESSES REDESIGN

During the redesign of the processes, mechanisms should be considered to automate some tasks, using the available technological capabilities. For instance, text-mining can help to automatically assign a category and a priority to a case, thus leaving more time for the customer support to interact with customers. Part of the process cannot be automated because it depends on the activities of the backend. This includes giving feedback to the customers, showing in this way their input is essential. This will motivate customers to keep sending reports, thus feeding the maintenance plan.

There are two main weaknesses in the current process (Figure 5.8): the fact that the customer support must analyse all the cases, and the fact that no feedback to the customer is assured after the problem has been handled. The lack of feedback makes the customer lose motivation and probably stop reporting further issues. Moreover, if the customer support is involved in all cases, the delay in responses will possibly be higher.

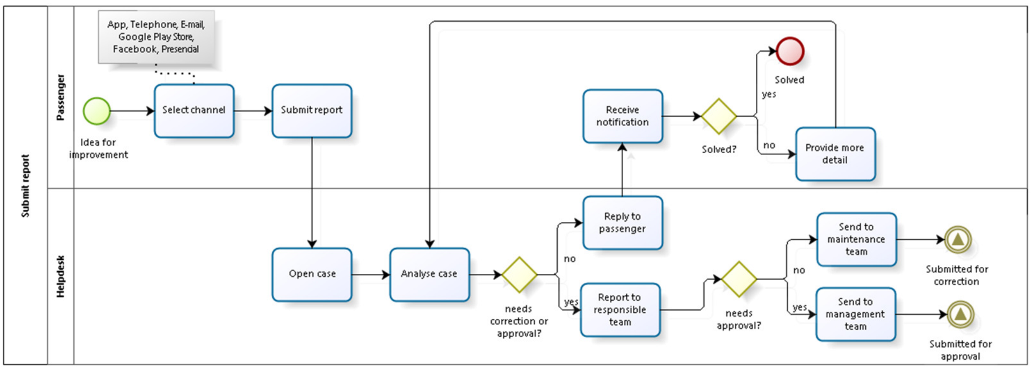

Figure 5.8. Submit report process (AS-IS).

To reduce these delays, we have redesigned the process, so that the category is automatically attributed to the report by the system, and not manually (Figure 5.9). It is important to simplify this part of the process because two of the most common reported issues (*Check-in* and *Redo enroll*) may hinder the beginning of the trip since, in these cases, the customer cannot use the mobile application, and may have to buy a regular physical ticket. If this happens too often, the customer is likely to stop using the app. Thus, this automatic classification procedure allows an immediate allocation of the case to the team responsible for handling it.

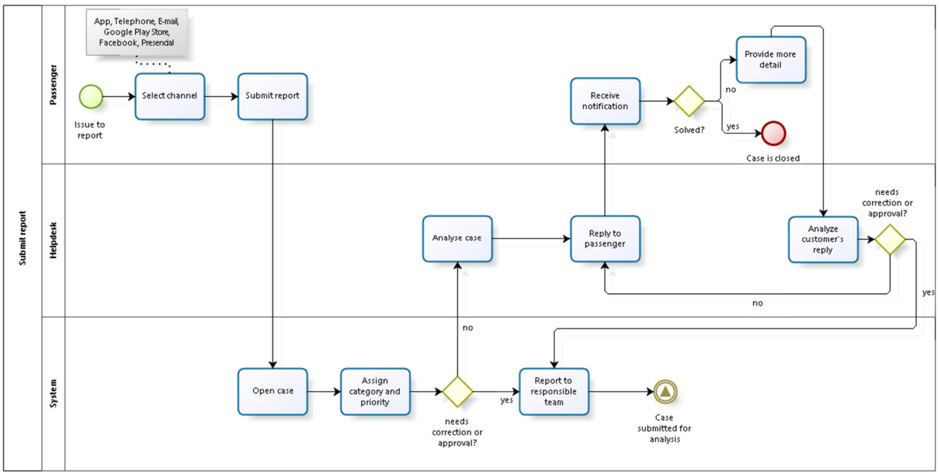

Figure 5.9. Submit report process (TO-BE).

Another advantage is that this automation reduces the workload of the customer support, thus providing more time for cases that require interaction with the customer (usage and usability problems). This small change in the process may have significant impact in the service, because it improves the communication with the customer and improves the information sent to the maintenance and management teams. This automation may also help in assigning each case to the right team, according to the category of the case, depending on if it needs approval or not (Figure 5.10).

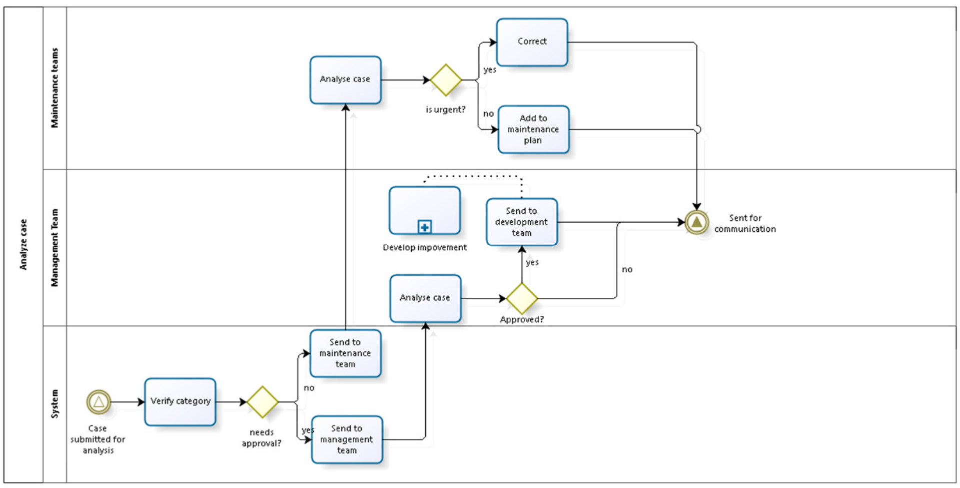

Figure 5.10. Analyse case process (TO-BE).

In the end, to keep the customer engaged, we have identified that the result of the case should be sent by the customer support and not automatically, as shown in Figure 5.11.

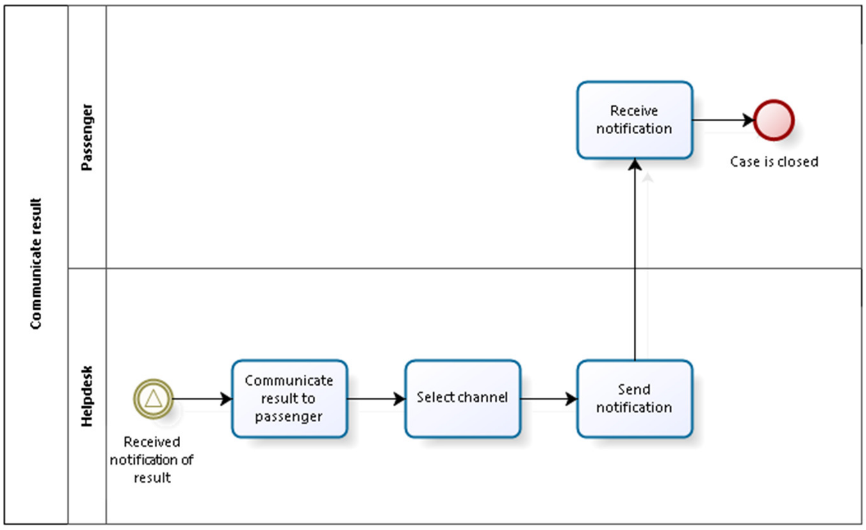

Figure 5.11. Communicate result process (TO-BE).

The analysis of both categories and processes shows how the workflow impacts the interactions between customer and service provider. The changes suggested in the mentioned processes will be reflected both in the mobile application and in the backend software, with implications in the *visualization* block, where these details should be accounted for.

Moreover, this case shows the importance of having an integrated system, since some cases need the intervention of a third party in the maintenance of the infrastructure (stops, ticketing devices, etc.).

5.4 Case 3

To redesign cities and develop new urban mobility solutions, urban planners need to accomplish successful public consultation processes. As traditional forms of communication no longer attract or engage participants, municipalities are starting to use digital channels in their communication strategies to increase citizens' engagement in contributing to the design of new policies. Using social-networks, e-mail, streaming sessions, online debates has been useful, but there are still some challenges to overcome.

In this case, we use our multidisciplinary approach to redesign the public participation process, based on an integrated information system. We have selected the urban planners as the main stakeholder, as they are responsible for the design of new urban policies, and have analysed how a good communication between urban planners and citizens benefits the process.

This case was developed in the city of Vila Nova de Gaia, in a collaboration with Gaiurb, the urban planning division of the municipality.

In addressing the five blocks of the framework (Table 5.8), we have collected information to describe the current context and to analyse methods and tools urban planners use to describe the current situation of the municipality. That information was collected during the meetings we had with municipality staff, and during the public discussion sessions we attended. The meetings were organized with the different divisions of the municipality administration (urban planning, mobility and transports, and citizen support) and involved two participants from each division (Appendix B).

Table 5.8. The relation between the conceptual framework and the process used in case 3.

Conceptual framework	**Case 3**
Context	Phase 1- Understanding the policy design process
Data sources	
Acquisition	Phase 2 – Analysis of communication tools and methods
Processing	
Visualization	Phase 3 – Rethinking policy design process

The information collected during these meetings and sessions gave us detailed insights about how citizens interact with the municipality, and on what are the challenges and barriers in the participation process. After understanding the current policy design process, we analysed existing tools and methods for engaging participants. In the end, we have made a set of suggestions on how digital tools can be used in the different moments of the process (Figure 5.12) and how an integrated information system can improve the development of a policy proposal.

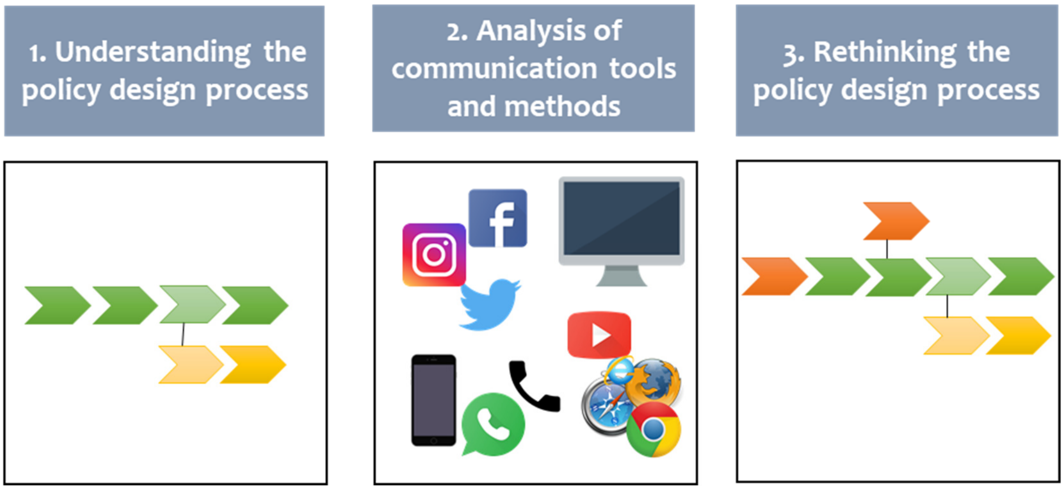

Figure 5.12. Process for case 3

5.4.1 Vila Nova de Gaia – the municipality

For this case we have considered the design of the master plan (plano director municipal – PDM) of Vila Nova de Gaia (Gaia), a Portuguese municipality in the Metropolitan Area of Porto. With a total area 168 km², Gaia encompasses urban, rural and industrial areas.

Besides the municipal administration, Gaia has 24 boroughs organized in 15 local administrations. The central administration has several departments and divisions, that include the municipal direction of infrastructure and public spaces (Direção Municipal de Infraestruturas e Espaços Públicos) and the municipal direction of urban planning and environment (Direção Municipal de Urbanismo e Ambiente). The first manages all cases related to the maintenance of public spaces. This includes repairing existing infrastructure, licensing new constructions, managing the transportation network, and handling the usage of public space (advertising, parking, restaurant terraces, etc.). The municipal direction of urban planning and environment is part of Gaiurb, a company owned by the municipality. Gaiurb was created in 2002 to improve urban planning management, and later, in 2011 it was merged with the divisions responsible for social housing management and urban regeneration.

In recent years, the municipality started the process of updating its master plan. This process required the participation of a multidisciplinary team since, in this version of the master plan, the goal is not only to tackle land use issues but also to tackle strategic mobility aspects of the city. The municipality has approximately 1,500 km of roads. Regarding public transportation, it has several bus companies operating within the area covered by the municipality (e.g., STCP, Espírito Santo, MGC, UTC), one light rail line (Metro do Porto) and part of one of the main train lines in Portugal (CP). In the near future, two more light rail lines will be built.

The municipality is also taking advantage of the current citizen participation to discuss other topics such as housing, social support (free public transport, affordable rents, e-commerce acceleration, etc.). Also, during the same period, there is a small-scale program to improve neighbourhoods with the participation of the residents (*"Meu bairro, minha rua" – My neighbourhood, my street*).

5.4.2 UNDERSTANDING THE POLICY DESIGN PROCESS

The process, determined by national regulation for the design of a municipal master plan, includes a mandatory public consultation period and public reports (Figure 5.13).

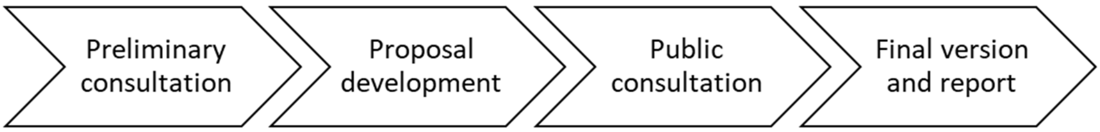

Figure 5.13. Standard public consultation process.

During the meetings we held with municipality staff, we learned that many citizens do not make valid contributions because, in fact, they do not know what is expected from them. It is easier for citizens to complain when a problem emerges than to present a strategic vision for the city. The participants also pointed out that communication, transparency, empathy, inclusion, and openness to new ideas and criticism are crucial for achieving acceptable engagement levels with citizens.

Portuguese municipalities update their master plans once every decade, this meaning that the last time Gaia updated its master plan, social networking and advanced mobile devices were still beginning. In fact, Facebook was created in 2004, YouTube in 2005, while the public consultation was already in process; and the first Android device was only available in 2008, in the end of the process.

In these new digital times, the municipality adopted different forms of communication, mainly in the preliminary consultation phase, that was now totally digital, and in the proposal development, that included participation via e-mail. The communication team has even created a dedicated page on Instagram and has used the municipality Facebook page for promoting the public events.

Nevertheless, the municipality still faced some barriers during this first phase. Though the e-mail and social networks were available, citizens were not aware that the public consultation was happening, and participation levels were rather low.

Then, the Covid-19 pandemic caused all discussion sessions to be held online. First, several sessions covering several topics were streamed on the municipality's pages. Then, 24 sessions covering the 24 boroughs were held via video-conference.

Even though there were participants from all age segments, it is not easy to assure a good level of representativeness. Many participants belong to associations (local state church communities, sports clubs, cultural associations, etc.), or they work in areas related to urbanism, and end up making biased comments in line with their own personal agendas. For this reason, municipalities need inclusive measures, using different communication tools. While some people are more willing to participate in a digital form due to the comfort and time required, other people still prefer human interaction and enjoy a face-to-face conversation. That is why some participants did not turn their cameras on and opted just to watch the discussion and not to participate. This suggests that, while the municipality must adopt digital forms of participation, traditional interactions cannot be abandoned.

During these online sessions, most comments were focused on local issues and did not reflect the strategic perspective required for a master plan. For instance, instead of mentioning the city needs more cycle lanes, people would rather say "where I live, there is no cycle lane". Other participants reported problems that could be easily solved, such as holes in the sidewalk, crosswalks with poor lighting, etc. This means that policy makers need to analyse all information collected and carefully select what is really of a strategic nature.

5.4.3 Analysis of communication tools and methods

One of the challenges of digital communication is the fact that different channels, tools, and methods have different capabilities and there is not a universal solution. Considering the information given by the municipality, we have compared the main methods used. We took into account the type of information and the format allowed by different channels, the type of user of those channels, and some advantages and disadvantages of each channel.

The way that social media platforms treat the different contents shared also influences the choice of what method to use in the promotion of the participation process. For instance, images provide limited information, but they reach more people. For that reason, they are useful in promoting the debate sessions serving the same purpose of flyers, even if they do not trigger any interaction. In the case of Gaia, the communication team selected Instagram to encourage citizens to send e-mails with their proposals, but the participation levels were not high. In fact, only after sending flyers via both physical and electronic mail promoting the debate sessions and letting people know that there was a dedicated Instagram page, that page gained attention.

In another perspective, a video explaining what is expected from citizens and the importance of participation could be more efficient. Videos contain more information and can increase awareness towards the importance of participating, and tell citizens what is expected from them, thus increasing the quality of participation.

The municipality opted to stream a set of thematic sessions via Facebook, that aimed at explaining current policies and asking citizens their opinions. In general, these sessions had a good acceptance from the citizens. Facebook offers features such as video, text, images, groups, events, and others, that can also be quite useful for this purpose.

The problem with those platforms is that they are not used by everybody and have quite different audiences (e.g., Instagram users tend to be younger). This could hinder the representativeness of the sample. This is a strong argument in favour of using a bundle of channels, and adopting different language and communication approaches, depending on the platform. Due to the algorithms of social media, important *posts* may not reach many followers. To overcome this issue, e-mail or physical mail can be used to guide people to consult a website or to join an online community.

One advantage of any social network is the fact that it is easy to raise questions. This happened during the live stream sessions held in the beginning of the process. This feature can be interesting but causes an increased workload for social media managers who need to select relevant comments.

In general, we might say that these tools are mostly useful in keeping citizens engaged before and after the debate sessions, until the end of the process. But the debate sessions require a different type of interaction. Surprisingly, the online sessions had a better acceptance than expected. Gaiurb reported a quite diversified sample of participants, probably because, with the pandemic, people got used to online activities.

It is also important not to centralize all online communication in third party platforms. Hence the importance of having a website. Gaiurb took this opportunity to redesign its website to facilitate interaction and to make it easier for citizens to find information regarding the ongoing process. Small usability details were important for increasing participation. For instance, the link to sign up for online debate sessions was made visible and a contact form was added.

5.4.4 RETHINKING POLICY DESIGN PROCESSES

The interviews allowed us to confirm that the main barriers for participation are the lack of trust in the authorities, and a low knowledge on how to participate. These issues suggest the need to capture citizens' attention even before the process begins, and show how important it is to participate. Then, when citizens are aware of the problem and willing to participate, they should be carefully informed on how to participate and what is expected from their contributions.

It is important to remember two of the three pillars of the framework – city as a service system, and co-creation. When designing a service, it is important to clearly communicate the value offer, the goals, and the vision. But, at the same time, it is quite important to be open to all suggestions. In the case of the urban policy design, it is important to communicate what are the goals of the new policy and the vision for the urban space. Nevertheless, urban planners should be open-minded and align the goals to the needs of the citizens.

For the purpose of this case, and to highlight the importance of communication, we consider a participation process with four phases, developed in parallel with the traditional process: awareness-raising, informing, debating, reporting (Figure 5.14). The main difference to the usual participation process is in the two first phases, since these were the phases where the municipality reported more difficulties in reaching citizens.

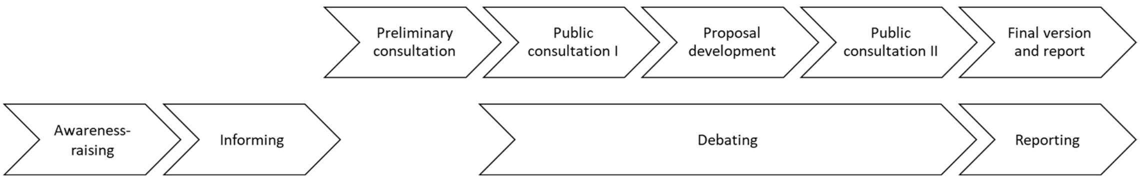

Figure 5.14. Public consultation process - additional phases to increase engagement.

The first phase aims at increasing the awareness for the importance of participation, by communicating the goals of the new policy. The second phase focuses on preparing citizens to participate, in order to improve the quality of the suggestions. This phase also includes the promotion of the different moments and forms of debate. The debate is then the typical exchange of ideas that includes several stages already in use and required by the Portuguese regulations. Finally, the fourth phase considers the importance of communicating the decisions and what changes are being implemented. The preliminary consultation phase should be developed as usually, with citizens submitting their requests.

In the first two phases of this process, as well as in the last phase, communication is mostly unidirectional (municipality → citizens). During the debating phase, communication must work both ways (municipality ↔ citizens). The possibility of interaction must be explicitly considered in this phase, despite of what channels are available. Since different channels reach different segments of population, the type of language adopted (vocabulary, informality, etc.) should also be adequate for the target population. Table 5.9 suggests what tools and channels to be used in each moment.

Table 5.9. Participation tools and channels for each part of the public consultation process.

	Tools	**Channels**
Awareness-raising	Video Newsletters Expositive text	Website Streaming services Social-networks E-mail
	Flyers Posters	Mail Advertising exhibitors
Informing	Video Expositive text	Website Streaming services Social-networks E-mail
	Letters	Mail
Debating	Online debate sessions E-mail Webforms Online questionnaires	Video-conference platforms E-mail Website
	Presential debate sessions Proposal submission (paper)	Local auditoriums
Reporting	Final report document Newsletter	Website Social network E-mail

The videos used to create awareness can be live videos presenting the goals of the participation, or pre-recorded narrated videos with animations and illustrations explaining the participation process and the goals of the new policy. In our case, the municipality chose to stream live videos on Facebook, but this was not enough for some participants in the debate phase to know what the objectives were.

During the debate phase, social networks can remain active since some questions and proposals can be submitted in the comment section. The problem with social networks is the constant need for moderation due to possible misconducts from participants. Still, participants who are willing to participate should be advised to submit their suggestions through other channels.

Furthermore, when developing a proposal, all the information collected in the first public consultation stage needs to be categorized and analysed by the different teams. Here, the *integration* proposed by this work can help in gathering information from the different sources (discussion sessions, e-mails, website forms, etc.) and in sharing the different inputs across the different teams. At this stage, the *acquisition* and *processing* blocks must consider the different types of users and the tasks they will perform.

It should be noted that one online session covers multiple topics and all the resulting notes must be analysed together with other information received by e-mail or other source. Centralizing all contributions in one information system guarantees that no information is lost and makes it easier for urban planners to maintain a holistic perspective of the new urban policies. For that reason, these digital channels and a set of adequate applications should be considered for the design of the integrated information system, in the *acquisition* and *processing* blocks.

The integrated system, in which citizens receive communications from the municipality, would also help to announce moments of participation, thus increasing engagement. Besides, the multilevel integration facilitated by the system would also benefit urban planners during the diagnosis phase (part of the preliminary consultation), by allowing them to consult information from the minutes of municipal assemblies, usually taking place once a month.

Since engagement levels should be guaranteed long before the participation process begins, other interaction processes can be redesigned using the same principles of the framework, as suggested in the next case.

5.5 CASE 4

In the previous three cases we have seen how good interactions of citizens with public transport operators and urban planners can improve mobility services and mobility planning. This fourth case adds, in an integrated perspective, the complexity of cases 2 and 3, and therefore, it may have some points in common with those cases.

Case 4 studies the interactions citizens may have with the municipality that impact their perception of municipality's operation and performance. This perception impacts their engagement in improving the city. For this reason, we study here the *value offer* of a municipality in the citizen support services, since these services usually include providing information and solving problems.

The process adopted in this case considers the pillars and the blocks of the framework as in the previous examples. This resulted in a three-phased process (Figure 5.15): understanding the service concept; describing the information system functional requirements; and designing the interaction processes. The phases of the methodology and the methods used in each phase relate to the conceptual framework, as shown in Table 5.10.

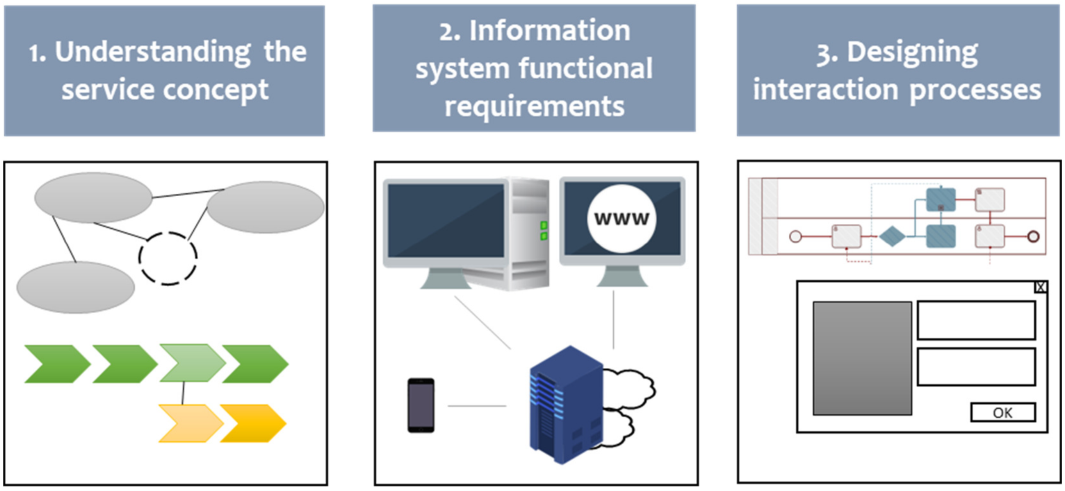

Figure 5.15. Process for case 4.

Table 5.10. The relation between the conceptual framework and the process used in case 4.

Conceptual framework	**Case 4**
Context	Phase 1 – Understanding the service concept
Data sources	
Acquisition	Phase 2 – Information system functional requirements
Processing	
Visualization	Phase 3 – Designing interaction processes

Understanding the service concept encompasses the analysis of the value offered through many interactions between the municipality and the citizens. This phase aims at understanding the structure and the activities of the local authorities (service providers) and at studying the stakeholders participating in each activity, thus reflecting the *social* and *urban* dimensions of this framework. This was accomplished through exploratory semi-structured or unstructured interviews with municipalities and experts, in order to describe the existing services.

Here, we follow the suggestions of MSD and SD4VN in designing the service concept in a many-to-many interactions context. Despite the hierarchical structure of the system (city, institutions, citizens), value is co-created through many-to-many interactions between different groups of stakeholders, as suggested in the SD4VN method.

After the characterization of the current service concept, it is possible to restructure the IS architecture (ISA), following the guidelines from the EAD method. Then, considering the selected channels, we must design the service touchpoints, i.e., the points through which the citizen can access the service. The resulting processes and their efficiency will depend on the municipality's organizational structure, that must be respected by those processes.

The *service experience blueprint* (SEB) or detailed business process maps (swimlane) can be used to design the multi-channel interaction processes, by defining each participant's tasks and by considering different utilization scenarios.

5.5.1 Porto Metropolitan Area (AMP)

This case is based on information collected in the Porto Metropolitan Area (AMP – Área Metropolitana do Porto). AMP is an administrative region in the northern coast of Portugal, that includes 17 municipalities.

These municipalities have designed and implemented quite different participation and collaboration mechanisms, based on their socio-demographic characteristics. However, there are also political choices and different organizational structures. For this reason, the sample used in our research considers the following municipalities: Gondomar, Maia, Matosinhos, Oliveira de Azeméis, Penafiel, Valongo, and Vila Nova de Gaia.

Five of these municipalities are in the centre of the AMP, closer to the central business district (CBD), and have a diversified land use, including urban, industrial, and rural neighbourhoods. One municipality is strongly industrialized and is located in the north of the CBD, but still has many rural areas; and the last one, that is mostly rural, lays in the south of the CBD. The participants in the interviews were chosen considering their responsibility (mayor, city councillor, head of the mobility department, and sometimes field engineers).

The data collected during the first phase of the process (*understanding the service concept*) was used to describe the current services and processes of each municipality. For this purpose, we made simple and semi-structured interviews, where processes were described by the participants. The information collected in this stage was also used in the analysis of the information system requirements and the redesign of the processes. Since the processes are different in each municipality, our analysis reflects the main successful procedures adopted by each city.

5.5.2 UNDERSTANDING THE SERVICE CONCEPT

The information was collected through interviews with staff of the municipalities, in order to obtain details regarding the interactions being analysed (Appendix B). From this information, it has been possible to understand the value offered to citizens through the services provided.

The stakeholders previously identified (section 5.1) were organized into three tiers (Table 5.11). The first-tier is related to their role in the city as a service system. The service providers or facilitators are the national, regional, and local authorities, along with the urban services, while the customers are the citizens.

Table 5.11. Stakeholders' groups

	Tier 1	Tier 2	Tier 3
Service providers/service facilitators	Regional and national entities	Authorities	–
		Transport operators	–
	Local authorities	Urban planners	–
		Mobility planners	–
	Urban services	Passenger services	Public transport operators
			Ridesharing, vehicle sharing, or ride-hailing services
		Logistics services	Home delivery and local store supply
			Wholesale and warehouse
		Other urban services	Utilities' maintenance
			Infrastructure maintenance
Customers	Citizens	Residents	–
		Workers	–
		Commuters	–
		Business owners	–
		Customers	–

The second-tier clusters stakeholders according to their primary service offering (urban planning vs. mobility planning; passenger transport vs. logistic service provider; etc.). Regarding the citizens (customers), the second-tier explicitly considers the role they play, which depends on their position in the system and on the time of the day, as their perspective towards the system changes accordingly. For example, a travelling citizen will have different needs, whether he/she chooses to go by car, to take the public transport, or to use a soft mode.

Finally, the third-tier views the stakeholders taking into account some of their specific characteristics (e.g., collective transport vs. individual vehicle). For the sake of clarity, in the case of citizens, we do not present the details here, as for each second-tier group, there are many third-tier subgroups.

Some groups could even have more tiers. For instance, it is possible to differentiate rail and bus in public transport operators. However, for the purpose of this analysis, the tiers defined here were considered to be enough.

When the system is viewed as a network, where there are many-to-many interactions, the role of the service provider can vary depending on the generated value and on the service that the customer is seeking. In general, local authorities become the service provider (black arrow, in Figure 5.16), having urban services and national and regional entities as service facilitators providing the service through secondary interactions (grey dashed arrows, in Figure 5.16).

However, in some municipalities, responsibilities are not centralized, and this may result in citizens having to seek the same service more than once. For instance, it may happen that the local authorities manage information regarding bus stop shelters, but the bus schedule is managed by the transport operator. In these cases, the citizen can contact directly urban services and not the local authorities (grey arrow, in Figure 5.16).

This case extends beyond urban mobility due to a suggestion of one of the experts interviewed who mentioned that, on the one hand, there are some topics where there is too much information, and people do not need more; but, on the other hand, some issues are still not easily handled. For instance, information on new developments and constructions may influence the decision of buying an apartment or a house, or the decision of starting a new business in a certain neighbourhood. And, for example, information about waste collection could lead citizens to only dispose their garbage in the correct days, hence making streets more pleasant with no waste accumulation.

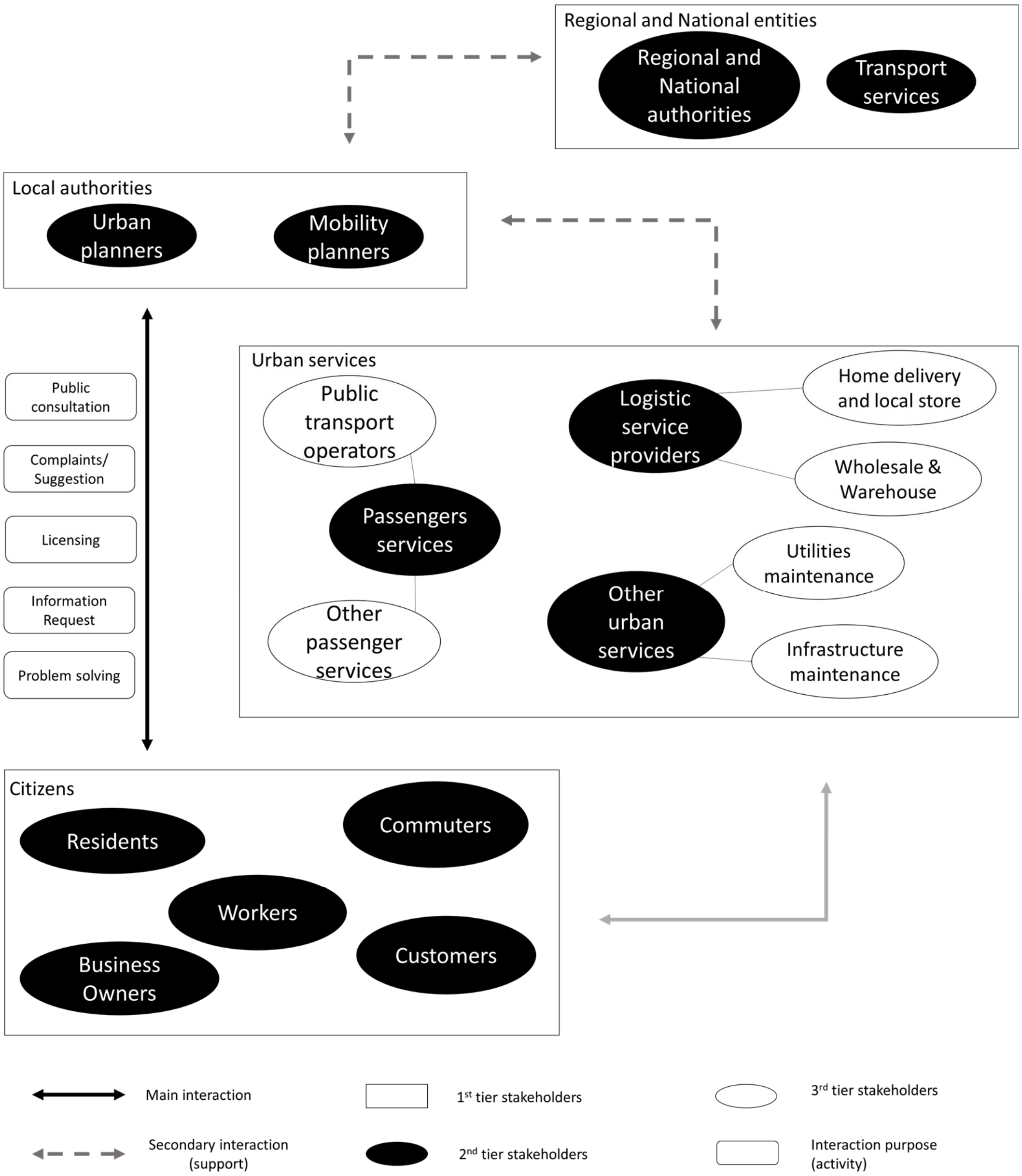

Figure 5.16. Urban mobility stakeholders and main urban services.

If the citizen knows who to directly contact, the process becomes leaner, and pressure is removed from central services. But, if that does not happen, the citizen may submit the same complaint to the central services and to the transport operator. In practice, this may increase the complexity of the process by creating duplicated cases, since the citizen contacts both entities.

At this stage, the different identified services were grouped into five main offerings: public consultation; licensing; information requests; complaints/suggestions; and problem-solving. Depending on the organizational structure of the municipality, the competencies to deal with these issues may be centralized or spread across different departments. In rural areas, the importance of borough councils increases, as proximity with local authorities also increases. In some cases, even the local state church can facilitate the contact with the municipality.

The municipalities follow the same (or similar) processes to deal with information requests, complaints/suggestions, and problem-solving cases. However, for the purpose of our work, these situations were analysed separately as they require different participants and different actions.

To better understand the value created in these services and how this value can be increased, services were compared, in terms of the number of participants and in terms of the actions required from the local authorities (Table 5.12). This will later help to select the best channels for each service.

Table 5.12. Main characteristics of the municipal services.

Services	**Example**	**Participants**	**Immediate response / analysis**	**Level of impact**
Public consultation	Consulting the population to propose changes to regulation before it is finalized.	Many	Analysis	Strategic
Licensing	Submitting a request to build a ramp for a private garage.	2+	Analysis	Tactical
Information request	Seeking information about a process or a service.	2+	Immediate response	Tactical or operational
Complaints / suggestions	Informing authorities that traffic lights are not working.	2	Analysis	Tactical or operational
Problem-solving	Asking for help in filling in a form.	2+	Immediate response	Operational

A brief analysis showed that the more participants are involved, the more complex the process is, and the more time it takes for the customer to receive an answer. Some processes cannot be changed because of local regulations, but the transparency of a project may help to manage citizens' expectations.

The operational cases with immediate response are more likely to be solved with only two participants (the citizen and a local authority). However, depending on the issue raised by the citizen, it may be necessary to involve urban services. The same happens for the licensing service. Complaints and suggestions only require two participants, since they end after a simple interaction to exchange information. When a suggestion requires a more significant intervention (e.g., changing the size of a sidewalk), it is then transferred to a list of activities related to improvement and maintenance.

The only process where there are multiple participants is the public consultation. In this case, local authorities lead the process. Still, it must involve the participation of a diversified set of citizens and the different urban service providers. In this case, we consider that there are many participants, as it is a process open to anyone interested.

The complexity of the process is also related to the decision at hand. Citizens' operational decisions are usually based on information requests, while citizens' strategic decisions may depend on licensing, for example when a new construction is being planned.

The case is different for the municipality since suggestions, for instance, can feed an operational decision but can also be quite complex and be used to feed a master plan, hence becoming strategic decisions.

Quite often, the effectiveness of the processes is more influenced by the organizational structure than by the level of digitalization. Results also show that more horizontal institutions have better results in communicating with citizens, since it is easier for a citizen to reach the person who can really solve the issue at hand.

5.5.3 INFORMATION SYSTEM FUNCTIONAL REQUIREMENTS

This phase of the process aims to describe the characteristics of the IS that will foster participation and increase the engagement of citizens with the urban services. This section describes some of those characteristics with a focus on the software applications that should be made available.

In a network of actors with many-to-many interactions, the IS must allow the different stakeholders to interact and access information, to enable fast and smooth interactions and improve their results. In the information provided by the municipalities, there are multiple channels through which value can be exchanged, in person, or using a digital interface.

The analysis of the five main service offerings (Table 5.12) results in an IS architecture that allows stakeholders to interact directly with any other stakeholder in the network. Instead of more traditional dyadic interactions (citizen – local authority – public transportation operator), a direct interaction between any pair of stakeholders (citizen – citizen, citizen – public transport operator, etc.) can take place. In the end, this will be a choice to be made by the specific local authority.

One of the municipalities (that participated in our survey) prefers to centralize and manage all information that reaches the citizens. This is possibly a valid approach for complaints and problem-solving scenarios, where the local authority acts as a moderator. However, a collaborative approach has the potential to reduce the workload of the municipalities. Interacting with other citizens can generate value when direct interaction with the municipality fails. To ensure the information is the same for everyone, a central server and a database storing data from various sources should be accessible by the different stakeholders.

Moreover, depending on the users' activities, other software may be built on the IS (web, desktop, mobile). For instance, the person(s) responsible for responding to citizens' requests should have a desktop application that integrates requests from different sources. But citizens should have a mobile application to send requests and receive notifications, allowing real-time communication.

Despite the advantages of social networking in connecting customers, interviewees showed some concerns about the quality of information shared on those platforms, suggesting some type of moderation would be required. One of the interviewees believes that a mobile application owned and controlled by the city would be more easily accepted, enabling collaboration between citizens, and allowing collected information to be used in future city planning decisions.

5.5.4 DESIGNING INTERACTION PROCESSES

This section presents a scenario to show how and when a process may fail, and how it can be improved, by describing an interaction process with answers to the *how* question of the Zachman Framework. This example involves citizens and local authorities.

Consider the owner of a private car who wishes to shift to soft modes but needs relevant regulation information (on issues such as parking, mandatory individual protection, speed, or available paths).

The conventional process to find information on regulations involves searching for online information (indirect interaction with the municipality), and directly contacting the city services by using info desk channels. However, there are two possible moments when the interaction may not be successful, thus deteriorating the user experience.

The first failed interaction may happen when the citizen (the system user) searches for information and does not succeed to get it. This may be caused by several reasons such as: the user does not know where to search; the user finds the information but is unable to understand it; the information had not been made available by the municipality; or the information the user finds is incomplete.

If this step is not completed successfully, the user will still need to contact the municipality directly. But some municipalities receive too many requests or complaints and can seldom answer quickly and in due time. That is when a second unsuccessful interaction may occur. To overcome this problem, introducing the possibility of getting information through other channels can have significant advantages for both the user and the municipality.

Since contacting the municipality can be quite slow, due mainly to waiting times, promoting contacts among citizens can have considerable benefits, with fewer requests being generated (Figure 5.17). Therefore, there will be two main advantages on the service provision side: more resources available to assign to other tasks; and more capacity to answer more requests.

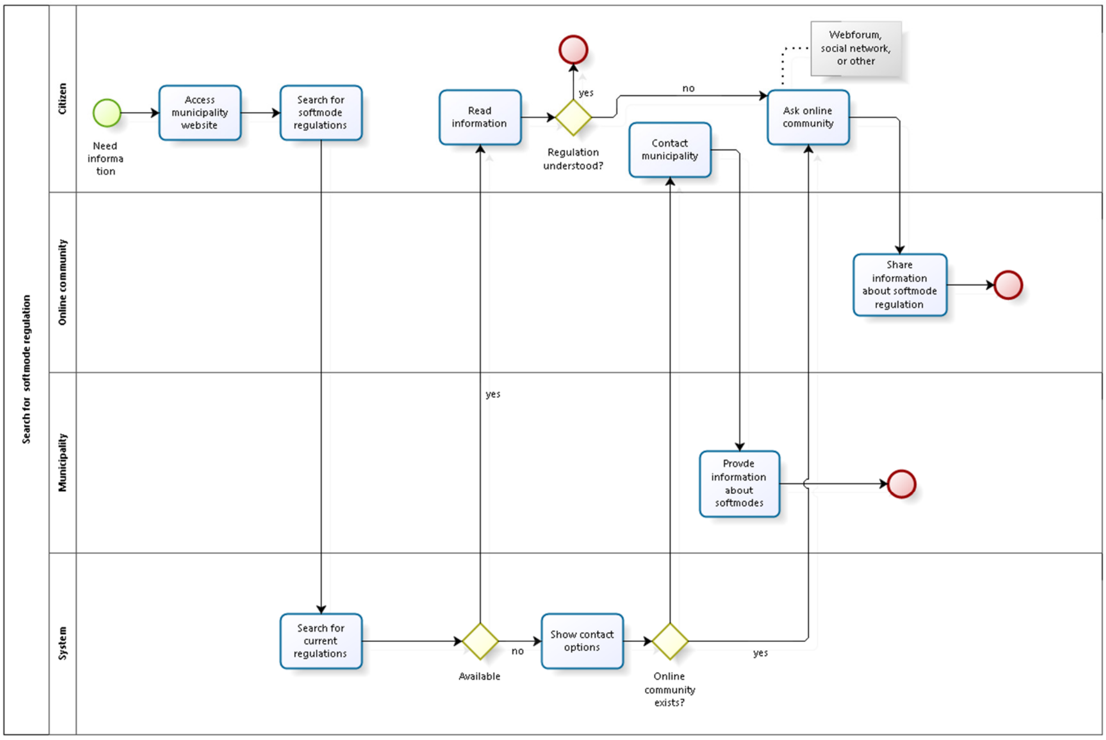

Figure 5.17. Business process diagram for the process "Search for softmodes regulation".

In the long term, redesigning the process of obtaining information can be beneficial for everyone. Some citizens will not even need to contact the municipality, and those who need to do it will be better served. The city will provide a better service level and have a better resources management.

In this example, the citizen does not require real-time information, as there is no immediate decision depending on that information. However, in some cases, access to information needs to be faster as shown by the first illustrative case.

5.6 SUMMARY

The cases described in this chapter deal with different aspects of the four dimensions previously presented (see chapter 4), thus confirming that urban mobility requires a multidisciplinary integrated approach.

All the dimensions are present, in some way and at different levels, in all the cases. The urban and social dimensions are visible mostly in cases 3 and 4. The technological dimension is highlighted in cases 1 and 2. And the organizational dimension is more significant in cases 2 and 4, whose situations depend on the organizational structure and the management strategies of the service providers.

In each case, we used the different blocks of the framework following a three-phase process, based on a similar approach that considers: (1) the analysis and understanding of the problem and its context; (2) the analysis of the information system requirements; and (3) the redesign of the processes. The fact that each case follows a different process, while still maintaining between the cases and referring to the framework, validates the framework and demonstrates its versatility.

Throughout this chapter, the complexity of the cases evolves from:

- a simple interaction of a user with the system, focusing on simple decisions made daily through indirect interactions (case 1);
- the interaction of passengers with a mobility service provider, representing the customer–service provider relationship (case 2);
- the interaction of citizens with urban planners in a participative process, using the same customer – service provider relationship but in the public administration (case 3);
- the interaction of multiple stakeholders, considering the actor-network and the bundle of services provided by the municipality (case 4).

The cases also show how the complexity of the urban mobility context requires a holistic view of the city. Even when dealing with a single stakeholder, the interactions with other stakeholders in different moments change the perception and information one has regarding the city, influencing the decisions making processes. Hence, this is a strong argument in favour of an integrated information system.

Finally, these cases helped understand how different stakeholders use the information and how processes should be redesigned to facilitate the access to information. As a result, a set of guidelines for building an integrated information system and increasing participation was developed. These guidelines are presented in the next chapter.

6

GUIDELINES FOR INCREASING STAKEHOLDER PARTICIPATION

6.1 INTRODUCTION

In this chapter, we further explore each of the previously studied cases, to unveil different facets of the framework, by highlighting one or more of its pillars.

Case 1 reinforces the need of providing tools for citizens to easily find and integrate information from different sources. This aspect is also present in case 4, pointing towards the importance of integrating various information sources in one single system. Integration of the management perspective is also present in case 3, when operational results are used to support strategic decisions.

Cases 2 and 3 highlight the benefits of knowledge co-creation for the service provider, by stating how public transport operators and municipalities can improve their services with customer/citizen input. Finally, case 4 presents the benefits of horizontal co-creation when citizens are able to share their experience and consequently enhance the experience of other citizens.

All four cases consider that there is value in having information to help build a city with a good quality of life, encompassing good environment, good urban planning solutions, good mobility, or good accessibility. This results from applying the S-D logic and from the fact that we view the city as a *service system*.

Not only the cases validate the multidisciplinary approach of the framework, they also provide insights on how the framework can support the development of an integrated information system. The recommendations that emerged from each case were organized in a set of guidelines related to the five blocks of the framework. This chapter describes those guidelines and how they relate to the framework.

6.2 GUIDELINES

The findings from each individual case resulted in a set of guidelines for the design and implementation of an integrated information system (Table 6.1).

Table 6.1. Guidelines resulting from the findings of each case.

Cases	Findings	Guidelines
1	To be well informed, citizens need information from multiple sources.	Provide the same information, in different forms, through different channels. Resort to multiple data sources to provide relevant and complete information.
2	Passengers are willing to share their experience to improve services. Feedback helps to keep passengers engaged in improving the service. Digital channels help to improve the efficiency of the backend.	Use data provided by passengers to identify problems. Provide feedback so that passengers are motivated to keep reporting their experience. Automate helpdesk processes so that the staff can focus on responding to open cases and maintenance teams have access to information faster.
3	Different population segments use different communication tools. Different channels should be adopted depending on the type of communication.	Adopt multiple channels to reach all stakeholders and to provide an inclusive service. Adopt different channels in different moments of the participation process.
4	Sharing information across different decision-making levels increases knowledge about the current problems of the city. Different roles need different tools and therefore require different applications. Good indirect interactions reflect the quality of the service and reduce direct interactions. Citizens can, in specific topics, provide information to each other. Third-party participants can help when information is not concentrated in one service provider.	Create a centralized server, with different access authorization levels, to make information accessible to all decision-makers according to their role. Do not only adopt multiple channels but also different software applications (e.g., desktop, website, mobile applications). Pay attention to the usability of digital channels. Allow for horizontal interactions. Design a system for a network of actors and not only for the duo service provider / customer.

Considering the findings and guidelines derived by the individual cases, we have developed two sets of broader and more generic guidelines: one set contains recommendations for the redesign of processes; and the other set presents recommendations for the development of information systems. Both sets contribute to the improvement of stakeholder participation in urban mobility services (Table 6.2 and Table 6.3).

Table 6.2. Set of guidelines for redesigning processes (PG – process guidelines).

PG1	Develop a communication strategy
PG2	Allow interactions on the network of actors
PG3	Automate processes when possible
PG4	Give feedback to customers/citizens
PG5	Focus on the main stakeholder in each proces

Table 6.3. Set of guidelines for developing the information system (SG – system guidelines).

SG1	Integrate data
SG2	Automate processes when possible
SG3	Include multiple applications in multiple channels

6.2.1 Guidelines for Redesigning Processes

PG1. Develop a Communication Strategy

Case 3 shows the importance of communication in keeping stakeholders engaged. Whether urban and mobility planners are designing a new urban policy or deploying a new mobility service, it is important to communicate well with the stakeholders involved. This includes defining what tools to use, when to use them, and what information is shared between those tools.

This will be visible in the *context* and *processing* blocks. In the *context* block, the type of communication is associated with the strategy for involving stakeholders (e.g., does the municipality prefer only formal channels, or will informal channels be available?). Then, in the *processing* block, we establish at which moments those channels are used.

PG2. ALLOW INTERACTIONS ON THE NETWORK OF ACTORS

Due to the complexity of interactions and the fact that information is spread among multiple groups, interactions should be hierarchical (citizen/customer → service provider 1 → service provider 2 (third party)), but the citizens will need to interact with different service providers in different moments (citizen/customer → service provider 1 + citizen/customer → service provider 2). Interviews performed for case 4 showed that, in some cases, even interactions between citizens could be beneficial. The interactions identified in the illustrative cases are summarized in Table 6.4.

Table 6.4. Types of interactions between urban stakeholders.

Interaction	Definition	Example
Direct	Interaction between active stakeholders	Asking for information about new transport prices (through phone, e-mail, or a web forum) and receiving an answer through the same channel
Indirect	When a stakeholder searches for information through official channels without contacting the other stakeholder	Searching for information about transport schedules on a website
Horizontal	Interaction between stakeholders of the same group	Interaction between two citizens
Vertical	Interaction between a service provider and the customers (different tiers)	Interaction between a citizen and local authorities
Main	Interaction between the two main stakeholders involved in the process	A citizen asking the municipality about information public transport route
Supporting	Interaction between a service provider and another service provider to solve a case raised by a third party (customer)	Interaction between local authorities and a public transport operator to answer a complaint of a citizen

The types of interactions need to be considered in most blocks due to the following:

- in the *context* block interactions between skakeholders are first analysed;
- in the *data sources* block interactions are again considered when analysing where data is available;
- the *acquisition* and *processing* blocks determine what type of interactions the system will allow;
- the *visualization* block considers the interactions when designing the workflow for each process.

PG3. AUTOMATE PROCESSES WHEN POSSIBLE

Case 2 provides an example where automating processes can improve the service experience by reducing the waiting time for a response, and at the same time, decreasing the workload of the customer support staff. While this may be clear for technicians, it is important to show the benefits of some level of automation for practitioners, who are traditionally quite resistant to change.

This guideline is also present in the group of guidelines for the information system as it is explained further ahead.

PG4. GIVE FEEDBACK TO CUSTOMERS/CITIZENS

Both cases 2 and 4 confirm the importance of giving feedback to customers/citizens, to show that their needs and problems are relevant for the municipality, for the transport operator, or for other service providers. This is also visible in case 3, when urban planners answer the questions of citizens on social networks.

Case 2 shows that a personalized answer is preferred over a standard one. However, this is not always possible and will depend on the situation. This guideline impacts the *visualization* block during the redesign of the processes.

PG5. FOCUS ON THE MAIN STAKEHOLDER IN EACH PROCESS

Processes involving multiple stakeholders, such as the example of case 4, may need detailed attention to the tasks performed by each stakeholder. To design efficient workflows of both frontend and backend tasks, highlighting the main stakeholder in each moment, allows a better design the process, improving the work of the staff, but at the same time enhancing the experience of the citizen/customer and contributing to more engaged stakeholders.

This guideline is related to the *visualization* block.

6.2.1 GUIDELINES FOR THE DEVELOPMENT OF INFORMATION SYSTEMS

SG1. INTEGRATE DATA

All the cases show that information retrieved from different data sources is required at various moments. To facilitate access to complete information, the IS must integrate data. Whether this data is retrieved from physical sensors or social media comments, it must be organized and structured so it can be helpful. Instead of duplicating data across different systems, to successfully create a collaborative environment where information is easily shared, there are two options:

- create a centralized, standalone system that stores all the information;
- or develop specific interfaces so that each service provider can maintain his own system but easily share information across the different systems.

For instance, case 2 describes a scenario where third-party applications are advantageous since information generated using the ANDA app can be sent to management information systems, to be integrated into management and maintenance plans.

While in small cities where there are fewer third-party players, a single system can be attractive, in more complex cases creating mechanisms for existing systems to share their data may be more feasible. However, data sets will need to have similar data architectures so that systems can be able to exchange data with few barriers.

This guideline is related to the *data sources* and *acquisition* blocks.

SG2. AUTOMATE PROCESSES WHEN POSSIBLE

As mentioned for PG3, automatic processes have advantages for the service provision. However, the level of automation depends on the available technology. For instance, when in case 2 we suggest that the system is responsible for assigning the category of the case (see Figure 5.9 from section 5.3.4), we assume that it is possible to implement text mining techniques.

In cases 3 and 4, when we suggest the integration of the social media comments and messages in customer support, this can also be automated if a mechanism is implemented to export those messages from the online platforms and import them in the system. Otherwise, if it has to be done manually, this process becomes inefficient.

This guideline must be present in the *processing* and in the *visualization* blocks.

SG3. INCLUDE MULTIPLE APPLICATIONS IN MULTIPLE CHANNELS

Case 1 is a simple process where one stakeholder interacts with the system (with indirect interactions with the service providers). However, it shows how different applications are required (a desktop or web application, and mobile applications). Moreover, cases 3 and 4 show how urban and mobility planners use diverse software. Therefore, multiple applications and interactions through different channels must be part of the IS (Figure 6.1).

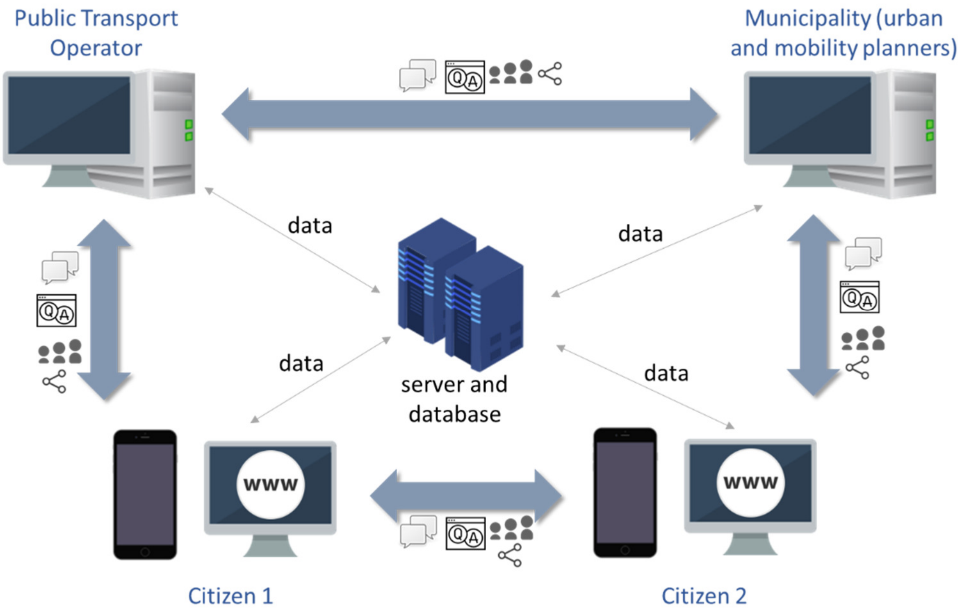

Figure 6.1. Scheme of vertical and horizontal interactions, for different stakeholders through multiple channels and applications.

These multiple applications will support the different tasks performed by the stakeholders. They may include management information systems for customer support, geographic-based applications with interfaces with geographic information systems for urban planners, optimization software for mobility planners, dashboards and mobile applications for citizens, etc.

The channels supporting the interactions include both digital and non-digital communication, namely telephone, mail, e-mail, social networking, chat and messaging tools, etc.

These channels and applications are primarily described in the *processing* block.

6.3 Analysis of the framework according to the proposed guidelines

The guidelines and the framework mutually contribute, in an iterative process, to their common development. While the framework provided the approach and logic used in the cases (chapter 5), the guidelines that emerged from the cases contribute to a critical analysis of the framework, highlighting the advantages and disadvantages of the framework (proposed in chapter 4).

We recall here the methods and tools present in each block of the framework (summarized in Table 6.5) and how they help to implement the proposed guidelines.

Table 6.5. Relationship between the guidelines and the framework's blocks and artifacts.

Framework blocks	Proposed artifacts (revision)	Guidelines
Context	Business process maps Strategic-operational summary	Develop a communication strategy (**PG1**)
	Actor-network map	Allow interactions on the network of actors (**PG2**)
Data sources	Decision matrices*	Allow interactions on the network of actors (**PG2**) Integrate data (**SG1**)
Acquisition	Relationship abstractions –entities	Allow interactions on the network of actors (**PG2**) Integrate data (**SG1**)
Processing	Relationship process – application Service System Architecture	Allow interactions on the network of actors (**PG2**) Automate processes when possible (**PG3/SG2**) Include multiple applications in multiple channels (**SG3**)
Visualization	Service Experience Blueprint Business process maps	Allow interactions on the network of actors (**PG2**) Automate processes when possible (**PG3/SG2**) Give feedback to customers/citizens (**PG4**) Focus on the main stakeholder in each process (**PG5**)

6.3.1 CONTEXT

The four cases show how information can change the decisions made by any of the stakeholders. In a context with multiple stakeholders, the city becomes an even more complex system, where actors interact in a network, shape each other's experiences, and create mutual value. The multiple links between different stakeholders, where there is no clear line of who is providing a service, create the perfect context for an S-D logic in studying the *city as a service system*.

The guidelines related to the *context* block result from considering the complexity of the interactions in the urban context and the need to keep stakeholders engaged in sharing information.

To develop a communication strategy, one needs to understand the activities that take place in the urban space and study the decisions stakeholders make, and how they affect the transportation system. The framework supports this analysis by considering business process maps as an effective tool, as demonstrated in cases 1 and 3. Only then is it possible to determine what information stakeholders need and how information should be presented.

The communication strategy should be reflected in how the municipality interacts with citizens, including the choice of channels to communicate, as demonstrated in case 3. Although, in that case, the channels are only selected in the third phase of the process, the main communication principles must be selected at the beginning of the process, after analysing the context. For that purpose, the strategic-operational summary must include if the service supported by the IS will focus on direct or indirect, horizontal or vertical interactions.

Case 4 shows how complex interactions can be due to the different roles each stakeholder plays in the urban context. Information does not exist in just one service provider. If we consider that anyone can generate information, then that person becomes a service provider as providing information is considered a service.

For that reason, an S-D logic approach considering many-to-many interactions, where anyone can provide and receive information, will allow the development of a system that supports all those interactions and fosters knowledge co-creation, and increases collaboration.

Those interactions are represented in a stakeholder map that allows the analysis of the service interactions that may occur – see the first phase of case 4 (understanding the service concept).

Moreover, the higher the complexity, the higher the number of interactions. We recognize that the complexity of situations such as case 4 can be quite challenging. Moreover, we believe this can be overcome if the stakeholder map is created in tiers, with different levels of detail according to the process under analysis. For instance, in case 4, we opted to have three tiers of stakeholders, and we zoom in on the interactions between residents and municipality (tier 2). We do not explore the interaction between citizens (tier 3).

6.3.2 Data sources

The information requirements previously identified can be structured using the decision matrices proposed in chapter 4, as shown in case 1. Then, it is necessary to determine where that information is available.

In case 1, we only have one row of the decision matrix since there is only one stakeholder. However, in some cases, more stakeholders mutually influence decisions. Thus, the decision matrix should have a row for each stakeholder (Figure 4.6). For instance, in case 2, we already had data from the customer support. But, if we did not have that information, we would have designed a decision matrix with two rows – public transport operator and citizen, hence representing the two perspectives of the process.

Moreover, as exemplified in cases 2 and 3, other stakeholders (even stakeholders from the same group) may own the information. That is why the IS must allow the interactions within the network of actors, described in the *context* block.

These cases also confirm the diverse sources of data and the need to integrate data, as presented before, in chapter 4. In case 1, we see that different indicators can be obtained from various sources, depending on the travel mode the citizen chooses. However, there is still the need to see all that information before deciding. This argues in favour of considering heterogeneous data that will later be integrated (referring to the *acquisition* block).

6.3.3 ACQUISITION

As explained in chapter 4, the *acquisition* block focuses on determining the entities and the data structure. Where the data architecture phase of the EAD proposes a relationship between entities and business processes, we additionally consider the relationship between entities and decision matrices.

Case 1 shows how the decision matrices can support the definition of the entities. Then, the process maps designed in the *context* block provide the moment for the need of those entities in the process (Table 6.6). In this situation (case 1), the motive of the trip is already defined (*why*) and the provision of the service is limited to the municipality and public transport operators (*who*). Now, we analyse the abstractions *where*, *when* and *how*.

Table 6.6. Relation between abstractions, information requirements and processes, considering the decisions from the decision matrix.

Abstractions	Where?	When?	How?
Decisions	Where am I going to? (destination) Which is the best path?	What time does it take to get there? What time is less congested?	Which is the best transport (private/public; individual/collective; on-demand; shared)?
Information requirements	Shortest path Accidents/Barriers	Schedules Number of transfers Congestion (duration of the trip)	Bus/metro stops Parking availability
Process	Decide path Adapt path	Decide the time of departure	Decide travel mode

It has been mentioned more than once that the same information can be valuable for all stakeholders, who will use it for different purposes. This generates heterogeneous data that needs to be integrated, organized, and structured. Moreover, the possible use of third-party applications to complete parts of the process demands the exchange of information between different data structures, meaning that the data architecture is dependent on the application architecture determined in the *processing* block.

For the above reasons, we have analysed the *acquisition* and *processing* blocks together in more than one case. The possibility of merging blocks according to the specificities of the case may determine how the framework is used in IS design.

6.3.4 PROCESSING

As stated through guideline SG3 (include multiple applications in multiple channels) all the cases argue in favour of having a bundle of channels and applications according to the different processes and the various stakeholders.

We have also established that both digital and non-digital communication channels must coexist, in order to create a truly inclusive service. However, the owners of the project (probably local authorities) need to determine what channels should be made available for each process and what applications will support the tasks of the stakeholders.

As mentioned in chapter 4, EAD establishes a relationship between processes and applications. With the same purpose, the Multilevel Service Design (MSD) suggests using the Service System Architecture. In our framework, we use the artifact from MSD to fulfil the application architecture of EAD.

Considering the services of case 4 (specifically the licensing service), consider now, for instance, a citizen who needs to licence the construction of an access ramp (to access a garage or to provide access to wheelchairs to a building) that will partially occupy the public space. Figure 6.2 shows an example of the service system architecture (SSA) for this case. To get the permit to build the ramp, the citizen needs to submit a request, then deliver documents, wait for the analysis, and receive the final decision. The SSA presents the channels and stakeholders that are part of each subprocess. For instance, the documents can be delivered in-person to the municipality staff or uploaded online. Urban planners also participate in the process because the front desk will forward the uploaded documents to them.

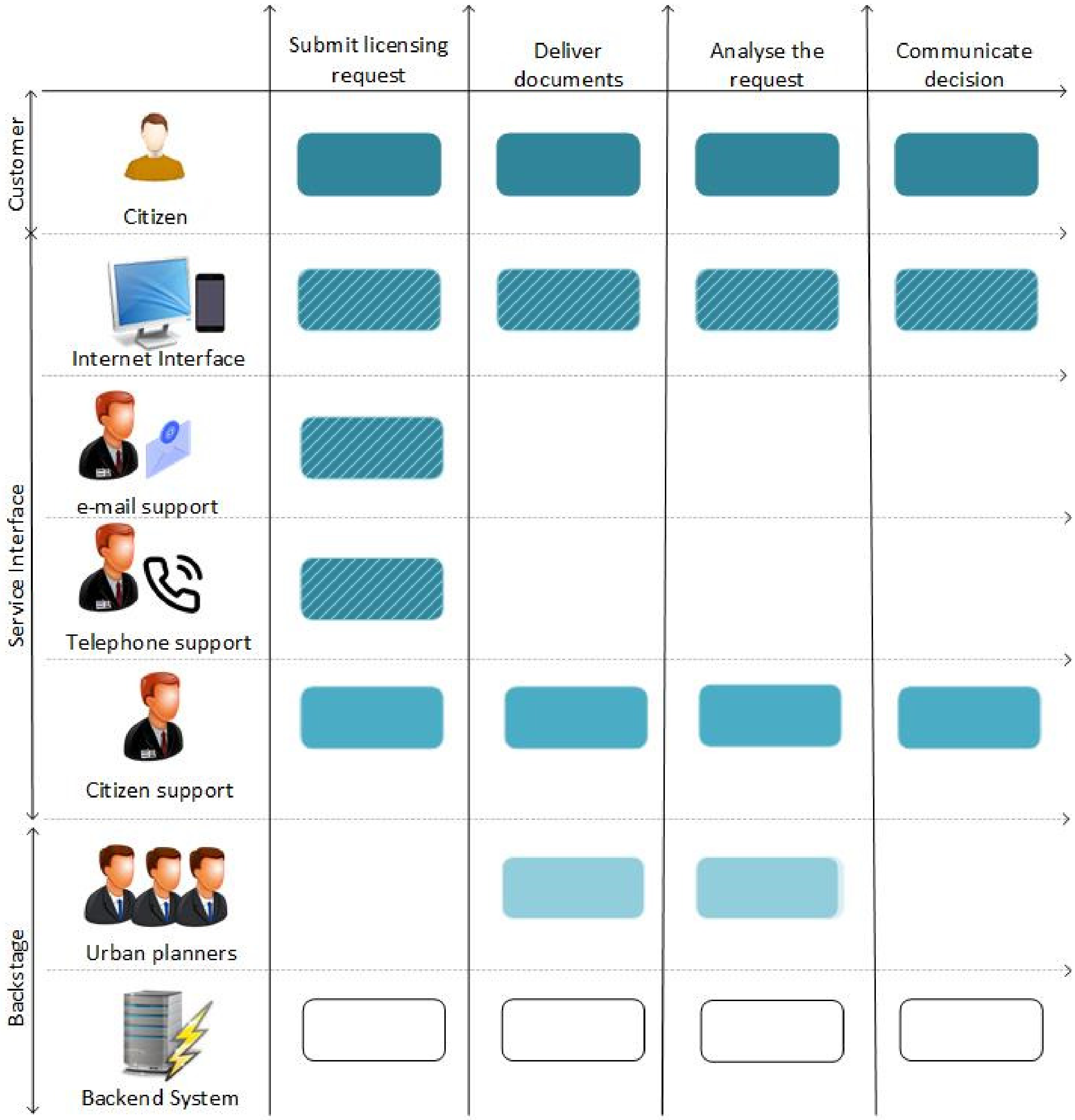

Figure 6.2. Service System Architecture for submitting a new licensing request.

This example was designed based on the perspective of the citizen. In order to determine the applications used by backstage stakeholders, we need to view the process from their perspective, bringing them to the top of the scheme. Note that, in the figure, the dashed rectangles indicate the interactions between service provider and customer.

6.3.5 Visualization

The *visualization* block is the one that focuses more on the service experience since the workflow determines if the information successfully reaches the stakeholder. In fact, four of the seven proposed guidelines can be associated with this block since they refer to the redesign of the processes (allow interactions on the network of actors; automate processes when possible; give feedback to customers/citizens; focus on the main stakeholder in each process).

Case 2 discusses the importance of giving feedback to customers as a way to keep and foster their engagement. That aspect also emerges in case 3, related to public discussion of urban policy.

Case 1 uses the service experience blueprint (SEB) for designing the process, showing the advantages of creating the process for the citizen/customer, while cases 2 and 4 use business process maps. In case 2, it is clear that business process maps help in the design of processes with more interactions and loops, but case 1 shows how the detail present in the SEB can be beneficial, depending on the process being analysed. We believe, therefore, that both methods are useful and should be selected depending on the complexity of the context. The more stakeholders a process has, the more detail we will need in each task; thus, the SEB will have the potential to create a good service experience. Again, the fact that we include the proposition of the stakeholder link to flow between subprocesses allows us to create an overall picture of the process. This is an additional reason to choose service experience blueprints when dealing with multiple stakeholders.

On the other hand, if we are analysing a process with only two stakeholders, as in case 2, and when we want to detail the automated tasks performed by the system, maybe BPM will be more appropriate.

Resuming the example of licensing an access ramp (section 6.3.4), we now exemplify how SEB would be used in that case. In order to design the complete process, we need to design four SEB (one for each process of the Service System Architecture, in Figure 6.2). As so, there are four sub-processes (*submit request, deliver documents, analyse request, communicate decision* – appendix C). To exemplify a process with both digital and non-digital channels, we have considered, in this case, that the documents must be delivered in person.

The process starts with the citizen searching for information on the requirements to apply for a ramp license and to submit a request. To start, the citizen can choose between a digital or a non-digital channel, following the guidelines proposed in this work. Then, using the *interface link* (see section 4.2.5), we continue to the service experience blueprint for delivering documents. In this part of the process, the citizen interacts directly with the citizen support staff, who interact with the system. Since the citizen is still involved in the process, we maintained the citizen in the top row of the diagram (Figure 6.3). However, during the analysis of the documents, the citizen does not have any action, and so we move the urban planners to the top of the diagram instead (Figure 6.4).

Regarding the indication of an interface to design, the example of the process Analyse Request show that the task “show PDF” does not have that indication, as it is not an interface with the system, rather it is a document uploaded by the citizen.

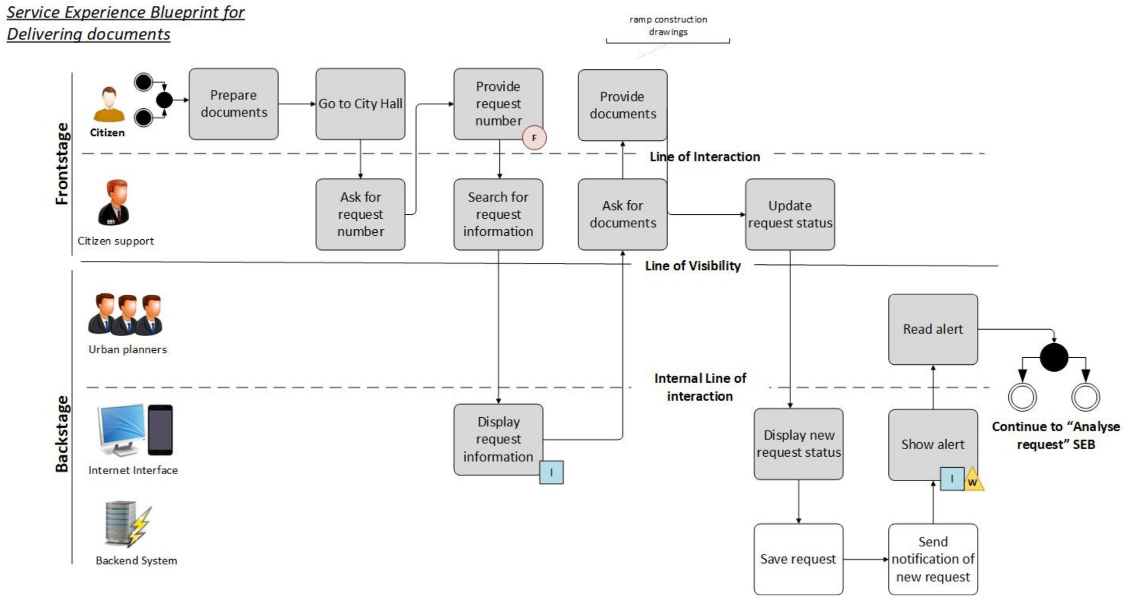

Figure 6.3. SEB diagram for delivering documents.

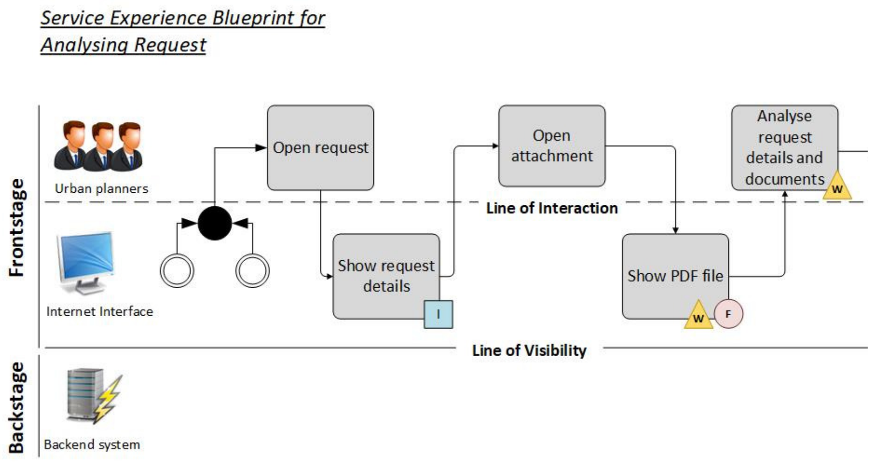

Figure 6.4. Partial SEB diagram for analysing request (full diagram in Appendix C).

In the final part of the process (*communicate decision*), the citizen is the main stakeholder and returns to the top of the diagram. Nonetheless, since both citizen and staff interact with the system, the diagram details two different internet interfaces: one with the interactions of the citizen and the other with the interactions of the support staff (Figure 6.5)

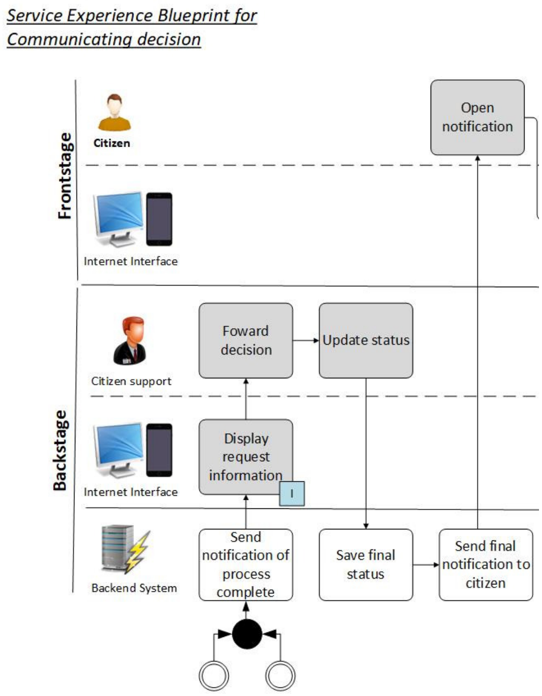

Figure 6.5. Partial SEB diagram for communication decision (full diagram in Appendix C).

6.4 Summary

The second analysis of each block and the guidelines that resulted from the illustrative cases, prove the potential of the framework. We confirm that the three pillars (*city as a service system, integration and co-creation*) and the four dimensions (*social*, *urban*, *technological*, and *organizational*) support the application of the multidisciplinary approach through the five blocks.

The five blocks of the framework provide a useful roadmap for rethinking urban mobility services and redesigning existing IS by using an S-D logic approach. The guidelines presented in this chapter reinforce the adoption of the S-D logic throughout this work.

In what concerns the practical application of the framework, we have shown in this chapter how service design methods, together with information systems techniques, can contribute to redesigning technology-based services in a socio-technical transition context.

It is clear that the multidisciplinary characteristics of the framework make it a somehow complex instrument. This complexity is, however, largely compensated by the possibility of using it in rather complex environments and of being able to adapt it to different urban contexts (small or large cities, few or numerous stakeholders, etc.).

7 CONCLUSIONS

The main objective of this thesis was to develop tools for enhancing urban mobility and transportation services by promoting the participation of citizens and fostering their engagement in a socio-technical transition period with fast-changing behaviours.

To achieve a sustainable and inclusive development, urban planning, urban mobility, and citizens' habits need to change in the city context. For that reason, new integrated approaches are required to promote the change of behaviours of the different stakeholder groups, with decisions grounded on relevant and proper information.

Urban planners need to improve their decisions in what concerns city planning and land use. Mobility planners and local authorities need to better design and manage more complex and technologically advanced mobility services. And citizens need to make better decisions to improve their life quality, by using the urban space and transportation systems better.

Such a complex context requires a multidisciplinary approach, aiming to promote participation, collaboration, and information sharing among the stakeholders, thus co-creating value in the urban context (co-creating the city, co-creating mobility services, and co-creating knowledge). To develop this new approach, we defined three main objectives:

RO1. To understand urban mobility through a multidisciplinary approach.

RO2. To develop a conceptual framework for redesigning information systems to support urban mobility management and urban planning.

RO3. To develop a set of guidelines to increase stakeholders' participation and collaboration in the urban context.

Throughout this dissertation, we have presented a research project aiming to accomplish these objectives.

In order to set up the proper context and frame the research, we have described, in chapter 2, the evolution of the urban space and urban mobility, and the current challenges municipalities are facing to create more sustainable cities. In chapter 3, we explored existing methods and tools used to support the multidisciplinary approach and the conceptual framework proposed in chapter 4.

Then, in chapter 5, we have presented four cases where the framework was applied, showing its versatility and potential. Finally, in chapter 6, we discussed the framework and a set of guidelines was presented for promoting the participation of stakeholders through the redesign of existing services and their supporting information systems.

A substantial part of this work was presented and discussed in international meetings and published as scientific papers (Appendix D).

7.1 Discussion and research contributions

The main contributions of this thesis are naturally related to the objectives established for the research and presented above. In the literature, we can find several attempts to apply the S-D logic to cities. Most of the works are based on the idea of the city as a service system, in a way somehow similar to what we do. Our focus on the citizen perspective as a customer, aiming to improve the quality of life of citizens (*the citizen experience*), is one factor that makes this research original. Based on the S-D logic, we have developed a multidisciplinary approach, accomplishing the first contribution of this research and fulfilling the research objective RO1.

This multidisciplinary approach is supported by three pillars (*city as a service system*, *co-creation*, and *integration*) inspired in the S-D logic and four dimensions (*social*, *urban*, *technological*, and *organizational*) that provide the novel, multidisciplinary nature of our approach.

Considering the above four dimensions and the approaches available in service design, along with the digitalization of services, we have integrated various methods from the information systems domain in the development of our framework.

The framework uses the proposed pillars and dimensions to support the development of information systems adapted to the complexity of the urban context. It is structured around five blocks (*context*, *data sources*, *acquisition*, *processing*, and *visualization*) related to the questions posed before making a decision (what is the decision; what information supports the decision; what data provides that information) and to the process of deciding (acquiring data; processing data into information; see the information; and actually deciding). Besides the existing artifacts from different areas, we propose the creation of *decision matrices* to organize the data to be collected, even before defining the data architecture. The framework fulfilled research objective RO2. Finally, after applying the framework to different cases, a set of guidelines was derived to foster the participation of the various groups of stakeholders by redesigning processes and considering some specific features for information systems.

7.2 FUTURE RESEARCH

Future work should encompass the four dimensions proposed in our approach to deepen the knowledge of cities as service systems. Accordingly, we consider four research directions associated with those dimensions. These directions may either consider each dimension independently or jointly tackle more than one dimension.

One interesting future research line is related to the territory, and the connections people establish with the territory, how they use it and move within it. Moreover, it would also be interesting to compare possible evolution paths of digitalization, and the relationship between mobility and different levels of technology adoption, and the impacts on the transportation systems.

To better understand how people interact in a digital world, the research could also focus on the impacts new forms of communication have on the public sector, resorting to practices in use by service providers. This might be the environment for some exploratory research to create guidelines for municipalities to successfully engage with their citizens.

Moreover, the recent acceleration of digitalization in the workplaces, due to the covid-19 pandemic, will strongly impact urban mobility. Therefore, designing sustainable cities and new mobility solutions will require understanding the evolution of the resulting mobility patterns in the next years. This will undoubtedly have relevant effects on city management and on how municipal administrations will organize their workflows.

Finally, another relevant aspect will be the evolution of urban areas and the organizational changes in public entities, since the growth of the metropolitan regions is leading to the transfer of competencies from local to regional authorities, creating new challenges in the relationship with citizens.

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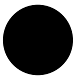
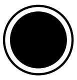
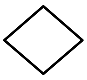
APPENDICES

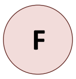
APPENDIX A - SERVICE EXPERIENCE BLUEPRINT NOTATION


Process start

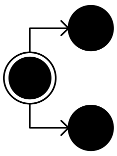

End of process

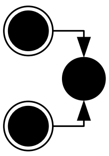

Decision gateway

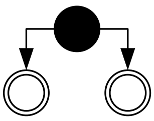
Waiting point

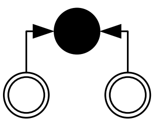


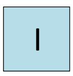
Fail point


Interface link (throw)


Interface link (catch)


Stakeholder link (throw)


Stakeholder link (catch)



Interaction point

APPENDIX B - INTERVIEWS

B1. List of Interviewees

Municipality	Name	Division and/or position
Vila Nova de Gaia	Paula Ramos	Gaiurb EM – Divisão de planeamento urbanístico
	Regina Sousa	Gaiurb, EM – Divisão de planeamento urbanístico
	Sofia Morais	Gaiurb, EM – Urbanismo
	Susana Paulino	Câmara Municipal – Divisão Mobilidade e Transportes
	Luís Brás	Câmara Municipal – Divisão Mobilidade e Transportes
	Susana Pina	Câmara Municipal – Gabinete do Presidente da Câmara
	Cristiana Nóbrega	Câmara Municipal – Equipa Multidisciplinar de Apoio aos Cidadãos
Matosinhos	José Pedro Rodrigues	Vereador de Mobilidade e Transportes
Gondomar	Luís Filipe de Araújo	Vice-presidente
Valongo	Paulo Ferreira	Vereador de Obras Municipais, Financiamentos Comunitários e Mobilidade
	Paula Marques	Divisão de Projetos, Obras e Mobilidade
	Carla Pardal	Divisão de Projetos, Obras e Mobilidade
Maia	Sandra Lameiras	Vereadora
Paredes	Luís Carvalho	Unidade de Sistemas de Informação Geográfica
Oliveira de Azeméis	António Pedro Castanheira	Departamento Municipal de Manutenção, Obras, Mobilidade e Equipamentos Públicos

B2. Interviews guiding script (Portuguese)

INTRODUÇÃO

O foco deste trabalho é a partilha de informação e como essa informação pode influenciar o comportamento dos utilizadores dos serviços de transporte.

Até ao momento percebemos que o desenho da cidade (infraestruturas e oferta de transporte) e a informação disponível são os factores que mais influenciam o comportamento das pessoas.

Isto pode ser visto em dois momentos:

- O desenho da cidade e dos serviços de mobilidade (participação pública)
- A utilização e melhoria da cidade e dos serviços existentes (acesso a informação e suporte)

Queremos rever como novos canais digitais podem facilitar o acesso a informação por parte da cidade, mas tb por parte dos cidadãos. E por isso necessário perceber como são os processos hoje em dia e como podem esses processos ser melhorados.

PRINCIPAIS TÓPICOS

Decisões de planeamento

1. Como se obtém informação para desenhar os novos planos?
2. Como se processa a análise dessa informação e qual o envolvimento dos cidadãos nos momentos de consulta pública?
3. Como avalia o processo e como pensa que é possível melhorá-lo?

Serviços de apoio ao cidadão

1. Quais os canais existentes?
2. Quem são os intervenientes?
3. Qual o processo atual que é necessário seguir quando um cidadão pede uma informação ou faz uma reclamação?
4. Como avalia o processo atual e como pensa que é possível melhorá-lo?
5. Que tipo de informação está disponível e que informação costuma ser requerida pelos cidadãos?

B3. Interviews guiding script (English)

INTRODUCTION

This work focuses on the processes of information and how information can change the behaviour of transportation services users.

Until this moment we have understood that the design of a city (urban infrastructures and transportation offer) and the information available are the factors that most influence the behaviour of people.

This is visible in two moments:

- Urban planning (both land use and urban mobility issues) – public participation in the design of urban policies
- Maintaining and improving infrastructure and current services (accessing public information or asking for support)

Our purpose with this conversation is to understand how new digital channel can facilitate the access to information. For that reason, we want to understand current processes and how they can be improved.

MAIN TOPICS

Planning decisions

1. How does the municipality gather information to create new urban plans?
2. How is that information processed and analysed? What is the citizens' involvement in public consultation moments?
3. How do you evaluate the current process and how do you think it can be improved?

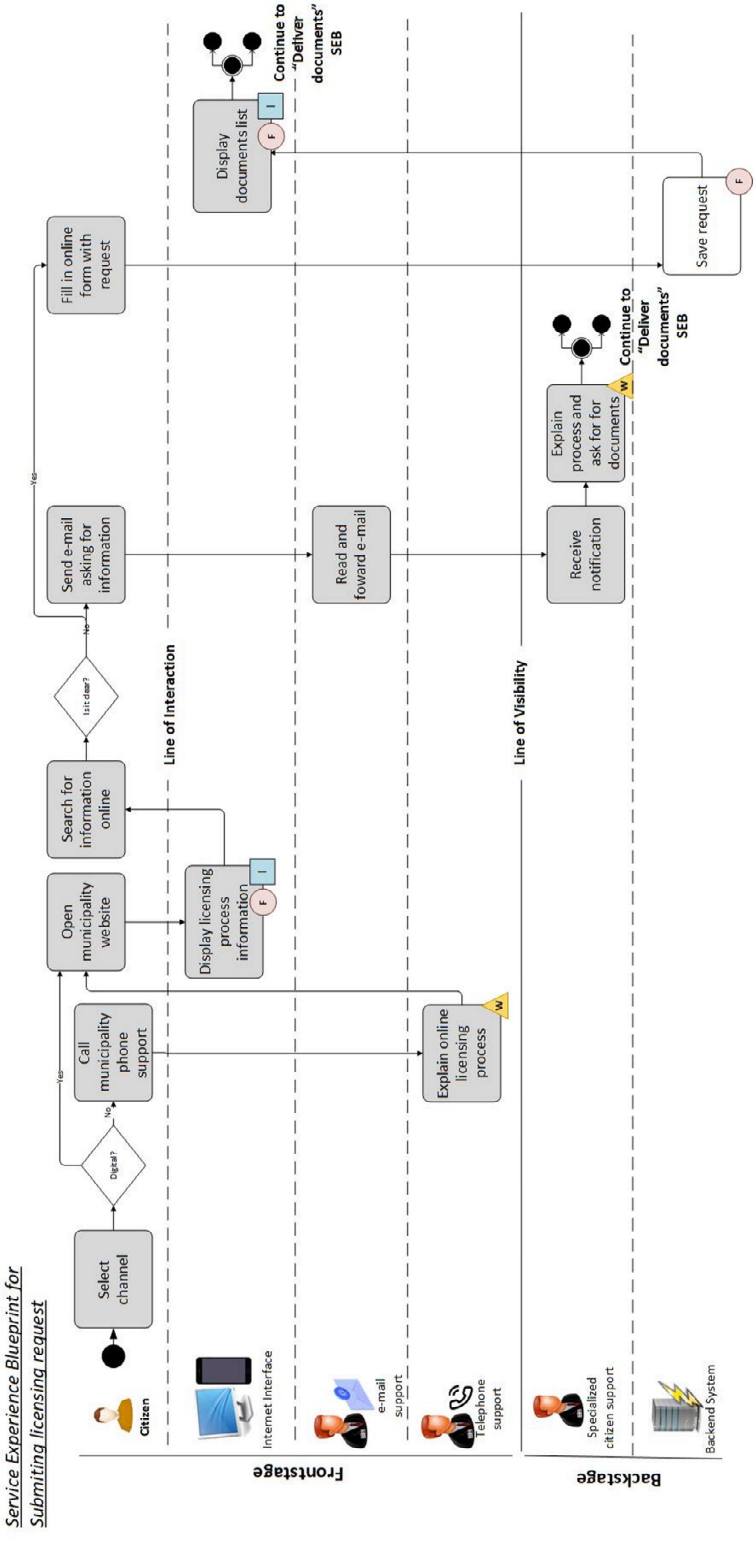
Citizen support services

1. What are the current available channels?
2. Who are the stakeholders in these processes?
3. What is the current process when a citizen asks for information or presents a complain?
4. How do you evaluate the current process and how do you think it can be improved?
6. What type of information is available and what information do citizens usually look for?

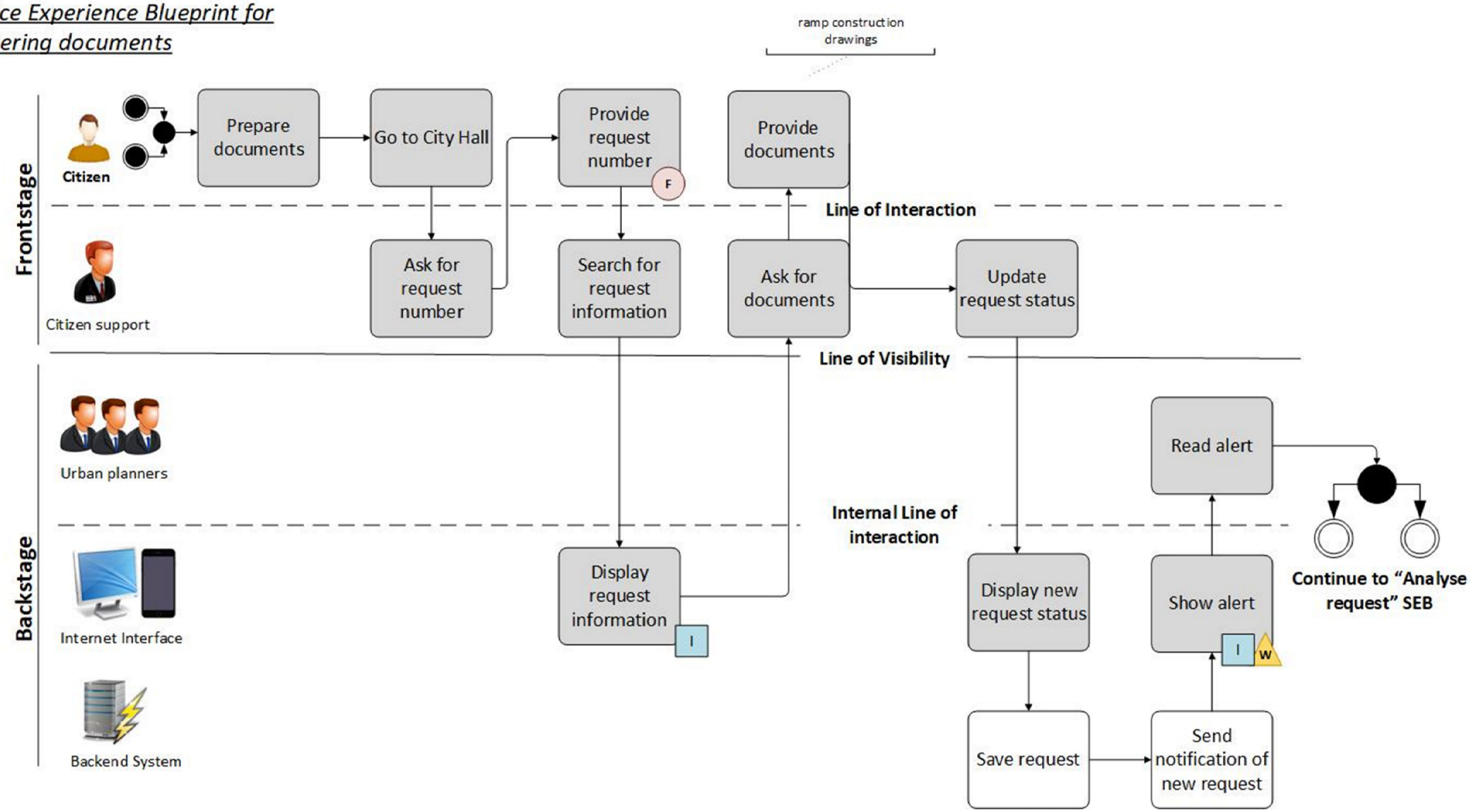
B4. Interviews highlights

Statement	Topic	Author
Digital tools used in the pandemic are here to stay and have proven to be successful. People tend to present their local problems and struggle to understand the big picture.	Urban planning	Paula Ramos
We are trying to keep a record of all suggestions (for urban planning), but some go to other divisions and we don’t have access.	Urban planning	Regina Sousa
It is difficult to keep up with the amount of cases that need an answer.	Urban mobility	Susana Paulino
People are sending suggestions, but they have unrealistic expectations.	Municipal services	Susana Pina
We have the tools for communication, but citizens do not use them properly.	Municipal services	Cristiana Nóbrega
We want to listen to people. There is one day of the week where people can come to my office, without an appointment, and present their problems and suggestions.	Urban mobility	José Pedro Rodrigues
People use the easiest communication tool they have, and we need to be available. But some requests need to follow the proper channels in our management system.	Municipal services	Luís Filipe de Araújo
We have found that transparency is key. When we started to publish all our expenses citizens started to trust us more.	Urban mobility	Paulo Ferreira
We try to answer any case and calmy explain people that some decisions are not up to us since we need to forward some cases to national transportation entities (CP, Infraestruturas de Portugal, and others)	Urban mobility	Paula Marques
A collaborative platform where citizens could interact directly and debate ideas for the city would be interesting.	Urban mobility	Sandra Lameiras
In rural areas the borough council has strong proximity with citizens and we even ask the priest/father to announce cultural events and urban planning debate sessions.	Urban planning	Luís Carvalho
In low population density municipalities it is almost like having two municipalities in one. The “city” in the centre and the rural areas surrounding that have completely different mobility needs.	Urban mobility	António Pedro Castanheira

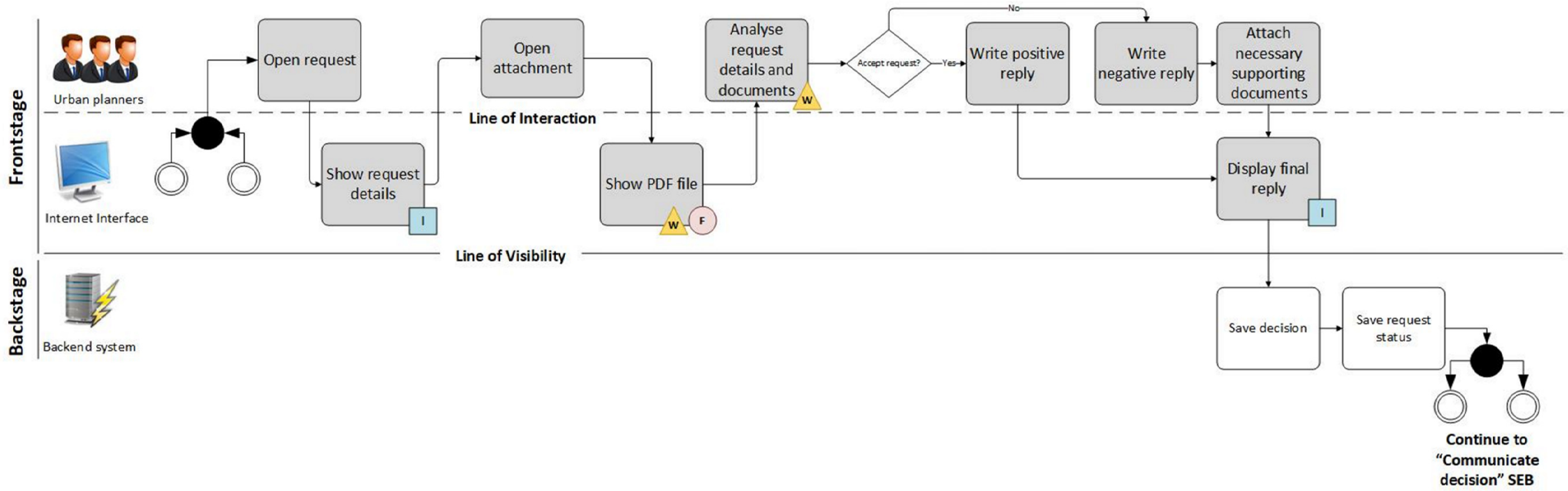
APPENDIX C - SERVICE EXPERIENCE BLUEPRINTS FOR LICENSING PROCESS



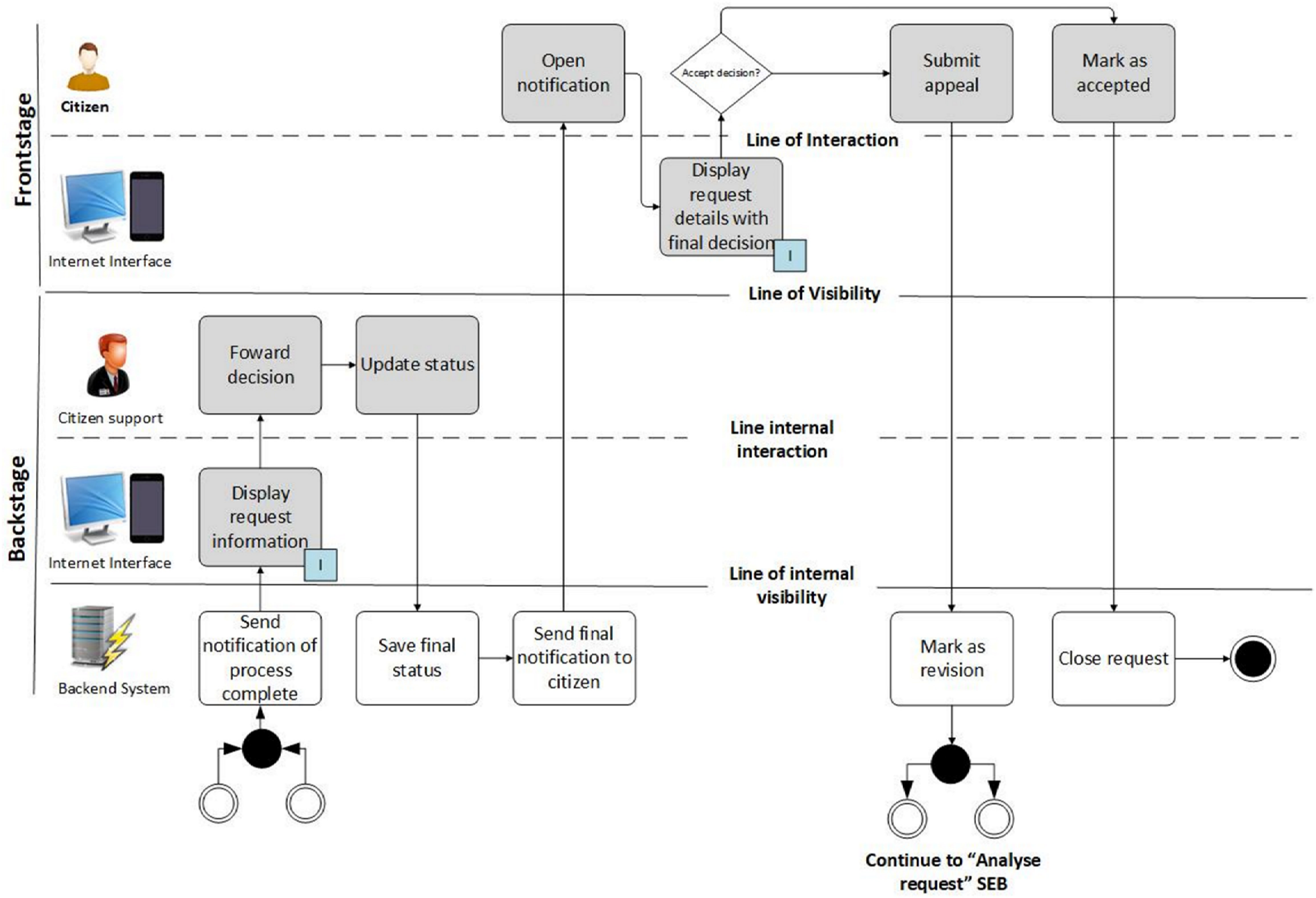
Service Experience Blueprint for Delivering documents



Service Experience Blueprint for Analysing Request



Service Experience Blueprint for Communicating decision



APPENDIX D - PUBLICATIONS

ABSTRACTS AND PRESENTATIONS

[accepted] Duarte, S. P., Freire de Sousa, J., Pinho de Sousa (2021) Designing urban mobility policies in a socio-technical transition context, 24th EURO Working Group on Transportation Meeting, EWGT 2021, 8-10 September 2021, Aveiro, Portugal

Duarte, S. P., Freire de Sousa, J., Pinho de Sousa (2019) An integrated information system to support decision-making in the context of transportation systems. In Pinho de Sousa, J., Campos Ferreira, M., (eds) Book of Abstracts - 1st Symposium on Transport Systems and Mobility.

CONFERENCE PROCEEDINGS

Duarte, S. P., Pinho de Sousa, J., Freire de Sousa, J. (2020) Improving urban mobility services through citizens participation in a socio-technical transition context. In Linden, I., Turón, A., Dargam, F., Jayawickrama, U. (eds) ICDSST 2020, 6th International Conference on Decision Support System Technology – Cognitive Decision Support Systems & Technologies https://icdsst2020.wordpress.com/program/publications/

Duarte, S. P., Freire de Sousa, J., Pinho de Sousa, J. (2019) A Conceptual Framework for an Integrated Information System to enhance Urban Mobility. In: Freitas, P. S., Dargam, F., Ribeiro, R., Moreno, J. M., & Papathanasiou, J.(eds) EmC-ICDSST 2019 5th International Conference on Decision Support System Technology–ICDSST 2019 & EURO Mini Conference 2019 on "Decision Support Systems: Main Developments & Future Trends" https://hdl.handle.net/10216/126619

Freire de Sousa, J., Pinho de Sousa, J., Duarte, S.P. (2019) "A Decision Support System to design multimodal networks for urban mobility". Proceedings of the XIX Latin-Iberoamerican Conference on Operation Research, CLAIO 2018 https://hdl.handle.net/10216/126612

BOOK CHAPTER

Duarte SP., Campos Ferreira M., Pinho de Sousa J., Freire de Sousa J., Galvão T. (2021) Improving Mobility Services through Customer Participation. In: Nathanail E.G., Adamos G., Karakikes I. (eds) Advances in Mobility-as-a-Service Systems. CSUM 2020. Advances in Intelligent Systems and Computing, vol 1278. Springer, Cham. https://doi.org/10.1007/978-3-030-61075-3_64

JOURNAL ARTICLES

[accepted for publication] Duarte, S.P., Pinho de Sousa, J., Freire de Sousa, J. (2022) "Rethinking technology-based services to promote citizen participation in urban mobility". International Journal on Decision Support Systems and Technologies – Special Issue on "Cognitive Technologies and New Trends in Decision Support Systems", Volume 14, Issue 1.

[accepted for publication] Duarte, S.P., Pinho de Sousa, J., Freire de Sousa, J. (2021) "A conceptual framework for an integrated Information System to enhance urban mobility". International Journal on Decision Support Systems and Technologies, Volume 13, Issue 4.