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Citizen Participation in Smart Cities

Facilitating Access through Awareness, Open Government Data, and Public Displays

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Citizen Participation in Smart Cities: Facilitating Access through Awareness, Open Government Data, and Public Displays

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“When you’re dead, you’re dead. But you’re not quite so dead if you contribute something.”

— Jim Lahey, Trailer Park Boys

ABSTRACT

In an effort to involve citizens in decision-making, more and more governments at various levels of power around the world are implementing citizen participation initiatives. Their objective is to reach decisions that are more in line with the reality of citizens and that are therefore better accepted. Citizen participation also aims to reconnect citizens with their governments, as citizens' trust toward them has reached particularly low levels in recent years. Furthermore, the emergence of new technologies and their use in city management, driven by the smart city movement, has opened new ways of reconnecting with citizens, and has therefore contributed to the recent hype for citizen participation.

Full of promise, the road to participation however is littered with barriers, which result in citizen access to participation not reaching its full potential. On the public servants side, the main barriers are the lack of expertise and resources to properly implement citizen participation initiatives and measure their impact, and the reluctance to hand over some of their power. On the citizens' side, there are also a number of hindering factors, such as lack of interest in participation, constraints related to personal life, and the lack of expertise or information.

New technologies offer ways to reduce these barriers to citizen participation. This is the objective of this thesis, which aims to provide solutions and recommendations to help reduce barriers to participation, with a focus on barriers on the citizen's side. Specifically, this thesis focuses on three barriers that were selected from a literature review and due to their particular relevance to the context of Wallonia (Belgium). The first is the lack of awareness of participation in smart cities. The second is the difficulty of accessing usable data needed to understand the topic on which citizens are asked to participate. The third is the barrier of entry to participation methods, which makes it difficult to attract citizens who are not already involved.

Since each of these barriers covers a specific aspect of access to participation, they were studied independently. As for the **first barrier**, the focus was on raising awareness of citizen participation in smart cities among children aged 12-14. A workshop adapted to the school context was therefore developed, and its impact was evaluated with 299 children through 15 sessions. The workshop conduct was thoroughly documented to allow teachers to organize it with their students autonomously. Concerning the **second barrier**, the starting point was Open Government Data (OGD), which is a rich data source made available to citizens via online portals. Since these portals are under-used in practice, a requirement analysis was conducted to understand what citizens expect from these portals. One of their requirements, namely to have data visualizations along with the datasets, led to the development of a guide for developers to choose the best mobility data representations. Interface design recommendations for developers and data publishers were also formulated to allow the development of portals that are more adapted to citizens' expectations. Finally, regarding the **third barrier**, this thesis has focused on public displays and on how they can be used as a citizen participation method. The strength of public displays is that they are directly integrated into the urban landscape, and therefore free from the entry barriers that commonly used methods have. In order to encourage the adoption of this device, which is rarely used in practice, an analysis of the existing literature was carried out to highlight successful experiments conducted with public displays and their results. On this basis, several research perspectives were also opened to reinforce the usefulness of public displays as a participation method. First, citizens' expectations on their involvement in the development of services such as public displays were collected. Second, a process model was developed to help developers design adaptive public displays that can encourage interaction by adapting to changes in their environment.

Keywords: smart city, citizen participation, barriers, education, Open Government Data, public display

RÉSUMÉ

Désireuses d'impliquer les citoyens dans les prises de décisions, de plus en plus de gouvernements à divers niveaux de pouvoir à travers le monde mettent en place des initiatives de participation citoyenne. Leur objectif est d'aboutir à des décisions qui sont davantage en adéquation avec la réalité des citoyens et qui sont donc mieux acceptées. D'autre part, la participation citoyenne vise à reconnecter les citoyens et leurs gouvernements, la confiance en ces derniers atteignant des niveaux particulièrement bas ces dernières années. Par ailleurs, l'arrivée des nouvelles technologies et leur utilisation dans la gestion des villes, portée par le mouvement des villes intelligentes, a permis d'envisager de nouvelles façons de reconnecter avec le citoyen, et a donc contribué au récent engouement pour la participation citoyenne.

Plein de promesses, le chemin de la participation est aussi parsemé d'obstacles, qui ont pour conséquence que l'accès des citoyens à la participation n'atteint pas son plein potentiel. Au niveau des agents publics, les principaux obstacles sont le manque d'expertises et de moyens en interne pour mettre en oeuvre correctement des initiatives de participation citoyenne et mesurer leur impact ou encore la frilosité de transmettre une partie de leur pouvoir. Du côté des citoyens, il y a également une série de facteurs entravants, tels que le manque d'intérêt pour la participation, les contraintes liées à la vie personnelle, ou encore le manque d'expertise ou d'informations.

Les nouvelles technologies offrent des moyens de réduire ces obstacles à la participation citoyenne. C'est l'objectif de cette thèse, qui vise à fournir des solutions et des recommandations pour réduire les obstacles à la participation, en mettant l'accent sur les obstacles côté citoyen. Spécifiquement, cette thèse s'intéresse à trois obstacles qui ont été sélectionnés à partir d'une revue de la littérature et de leur pertinence particulière dans le contexte de la Wallonie (Belgique). Le premier est le manque de sensibilisation à la participation dans les villes intelligentes. Le deuxième est la difficulté d'accéder à des données utilisables nécessaires pour pouvoir comprendre le sujet sur lequel on demande aux citoyens de participer. Le troisième est la barrière d'entrée des méthodes de participation, qui rend difficile d'attirer des citoyens qui ne sont pas déjà impliqués.

Étant donné que chacun de ces obstacles couvre un aspect spécifique de l'accès à la participation, ils ont été étudiés de manière indépendante. En ce qui concerne le **premier obstacle**, l'accent a été mis sur la sensibilisation des enfants de 12 à 14 ans à la participation citoyenne dans les villes intelligentes. Un atelier de sensibilisation adapté au contexte scolaire a donc été développé, et son impact a été évalué avec 299 élèves au travers de 15 sessions. Son déroulement a été documenté de sorte à permettre les enseignants de l'organiser avec leurs élèves de manière autonome. Pour le **deuxième obstacle**, le point de départ a été les données ouvertes gouvernementales (DOG), qui constituent une riche source de données mise à disposition des citoyens via des portails en ligne. Ces portails étant en pratique très peu utilisés, une analyse des exigences a été menée pour comprendre quelles sont les attentes des citoyens vis-à-vis de ces portails. Une de leurs exigences, à savoir disposer de visualisations de données, a conduit au développement d'un guide permettant aux développeurs de choisir les meilleurs représentations de données de mobilité. Des recommandations de conception d'interface à destination des développeurs et publieurs de données ont également été formulées pour permettre le développement de portails plus adaptés aux attentes des citoyens. Enfin, concernant le **troisième obstacle**, cette thèse s'est intéressée aux affichages publics et à la manière dont ils peuvent servir de méthode de participation citoyenne. L'atout des affichages publics est qu'ils sont directement intégrés au paysage urbain, et donc exempts des barrières d'entrées qu'ont les méthodes couramment utilisées. Afin d'encourager l'adoption de ce dispositif encore peu utilisé en pratique, une analyse de l'existant a été effectuée afin de mettre en lumière les résultats de la littérature. Sur cette base, plusieurs perspectives de recherche ont également été ouvertes pour renforcer l'utilité des affichages publics comme méthode de participation. Premièrement, les attentes des citoyens concernant leur participation dans le développement de services tels que les affichages publics ont été recueillies. Deuxièmement, un modèle de processus a été développé pour aider les développeurs à concevoir des affichages publics adaptatifs qui encouragent à l'interaction en s'adaptant aux changements dans leur environnement.

Mots clés : ville intelligente, participation citoyenne, obstacles, éducation, données ouvertes gouvernementales, affichage public

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CONTENTS

LIST OF FIGURES

List of Tables

CHAPTER 1

INTRODUCTION

The increasing urbanization of the population (United Nations, 2014) complexifies the handling of urban issues such as climate change, waste disposal, and traffic management (Caragliu and Del Bo, 2009). Originally driven by public funding given to large tech companies (Praharaj and Han, 2019), the smart city emerged as a potential solution to tackle these issues. The smart city grew fast in popularity, and numerous cities worldwide are engaging in efforts toward becoming a smart city (Giffinger and Gudrun, 2010). This includes major Belgian cities such as Brussels, Namur, Ghent, and Liège. However, several visions of the concept exist, and what "becoming a smart city" concretely entails varies. Nonetheless, a common ground can be observed in most smart city strategies, namely that citizen participation in policy-making is a central concern, and is necessary to help define a smart city.

Thus, driven by the rise of smart cities, more and more governments at diverse levels of power are engaging in citizen participation. Although this process promises many benefits such as more adapted and better accepted decisions and increased trust in the government, it is also fraught with obstacles. On the public servant side, some of the most recurrent ones are the lack of resources, time, and skills to implement and monitor the participation (Simonofski, 2019). On the citizen side, one can note the perceived uselessness of participation and the difficulty to fit participation in an already busy daily schedule (King et al., 1998).

Citizen participation is not a new concept (Arnstein, 1969), and barriers to participation have been studied several decades ago (King et al., 1998). However, they are still relevant today, and citizen participation does not reach its full potential. Nonetheless, the smart city and the technologies linked to it constitute new opportunities to alleviate them. This thesis focuses on the barriers to citizen participation on the citizen side, and more specifically on three barriers. It aims at providing tools and recommendations to help public servants and developers to alleviate them by exploiting those new opportunities brought by the smart city paradigm. These three barriers were selected from a literature review and from their particular relevance to practice within the Wallonia (Belgium) context.

The first barrier is the **lack of education to the participatory smart city**. In smart cities advocating citizen participation, citizens are expected to take on different roles including democratic participants (Simonofski et al., 2018a). At the same time, the very concept of smart city and the role of citizens is difficult to understand (Mohseni, 2020) due to the many visions of the smart city (Dameri and Cocchia, 2013) and the related fuzzy political discourses (Basu, 2019). This is problematic, as citizens cannot feel concerned by a concept they do not understand and in which their role is unclear.

To address this barrier, we[1] propose to target children aged 12 to 14. Educating children to participation is recommended in the literature (King et al., 1998) and matches the requirements of the upcoming reform of education in Wallonia. As a response to both this call from the literature and this practical context, we have developed a workshop aiming at educating children to the participatory smart city concept. It was designed to fit in-school timing constraints and was validated extensively. The validation showed that the workshop was successful in changing the vision of the smart city children had (which was solely technological) toward a more participation-oriented one. Feedback on the workshop led to developing another version supported by a tangible interaction table. The information provided in this thesis as well as the external resources it points to allow teachers to organize the workshop in their class autonomously.

The second barrier is the **difficult access to usable data**. Once citizens understand their participative role in the smart city, they need to understand the matter of the participation (Irvin and Stansbury, 2004). Therefore, citizens must be provided with sufficient data describing this matter in a form accessible to them. We set the focus on Open Government Data (OGD), as this data covers a wide range of urban issues and is being published by governments at an increasing rate. It is thus a very useful data source to support citizen participation. However, few citizens actually use OGD because it is made available mainly through online portals tailored to citizens with technical expertise.

The issue with OGD is to provide it to citizens in an appropriate manner so that they can assimilate it. Therefore, we have elicited the requirements of citizens regarding the online portals that are currently implemented to give access to OGD, and we refined the analysis with a study of the impediments experienced by expert citizens when using OGD in a project. We found that these portals are well-suited for experts but not for lay citizens, and that visualizations should be used more extensively to present OGD. As a result, we formulated interface design recommendations to OGD publishers and to portal developers to help them build portals that are tailored to lay citizens. Also, from a systematic literature review, we developed a guide helping OGD portal developers to choose the most suited visualization techniques to represent

[1] The thesis is written in the "We" pronoun to acknowledge the contribution of other researchers. The research reported in this thesis is based on scientific publications co-authored with them.

mobility data. These contributions are useful for OGD publishers and developers to make OGD more accessible to lay citizens.

The third barrier is the **entry barrier of current participation methods**. Once citizens are sufficiently informed, there remains the question of the methods through which they can be involved concretely. Several methods exist to implement participation (Simonofski et al., 2019b). However, the most used in practice (i.e. online platforms, scheduled meetings) require a step forward on the citizens' part, which makes it difficult to attract citizens who are not already engaged in participation. We focused on public displays (i.e. interfaces deployed in the public space). This particular device was selected because it is exempt from the aforementioned entry barrier. Thus, they have been observed to collect a much greater quantity of citizen feedback (Goncalves et al., 2014; Johnson et al., 2016b).

To tackle this barrier, we have conducted a systematic literature review to describe how public displays are currently used as a participation method, and how citizens are involved in their development. It allowed us to define four leads for further research on public displays and citizen participation. We further explored two leads, namely (1) involving end-users early in the development to better capture their requirements and encourage their acceptance of the display, and (2) introduce interface adaptation in public displays to cater for changes in users and environment and in turn provide a more appropriate participation experience. For Lead (1), we have conducted a questionnaire-based survey research to capture citizens' expectations toward electronic public services. For Lead (2), we developed a process model helping developers to model adaptation features in public displays. These contributions are useful to public servants willing to draw inspiration from the success stories reported in the literature review and from the innovative avenues proposed. The survey on expectations is useful for public servants to involve citizens in the development of public displays in the most appropriate manner.

1.1 Outline

The remainder of this thesis is organized into four parts.

Part I presents the relevance of the research presented in this thesis. The relevance for research is discussed in Chapter 2. It traces the history of the smart city concept from its emergence to the different visions of the concept, zooms on the participative vision with a discussion on how citizen participation is defined and implemented within the smart city, and details how the three studied barriers were identified from the literature. Chapter 3 presents the relevance to practice by detailing three challenges for practice existing in Wallonia related to the three barriers identified earlier.

Part II presents the research design followed to address the three barriers. The barriers, research gaps, and challenges for practice identified in Part I are mapped to three research questions in Chapter 4. The overall research methodology is detailed and instantiated for each research question in Chapter 5.

Part III presents the contributions developed for each research question in dedicated chapters. The first barrier is addressed in Chapter 6. It presents the workshop reusable by teachers to introduce the participatory smart city, as well as its validation and leads for improvements. Chapter 7 moves on to the second barrier and provides an analysis of citizens' requirements toward OGD portals and a mobility data visualization guide based on a literature review. A list of recommendations resulting from these contributions then closes the chapter. Lastly, the third barrier is tackled in Chapter 8. It presents a systematic literature review on public displays showing how they can be used to support citizen participation as well as leads for further research in this direction. It led to an analysis of citizens' expectations toward digital government and to the development of a process model for adaptive public displays documented at the end of the chapter. Each chapter provides specific methodological details that supplement Chapter 5.

Lastly, Part IV reflects on the results presented in the previous part. Chapter 9 summarizes the contributions, discusses their implications for research and the extent to which they answer the three research questions, explains the impact of the contributions on practice, and presents five general limitations of this thesis as well as the leads for further research they suggest. Chapter 10 presents four additional directions for future work that were not derived from the limitations. Chapter 11 closes this thesis with brief concluding remarks.

Part I

Background and Problem Statement

CHAPTER 2

RESEARCH BACKGROUND

This chapter starts by describing the developments that led to the origins of the smart city concept and the multiple visions that characterize it (Section 2.1). Then, it delves deeper into the vision of interest of this thesis, namely the participative orientation (Section 2.2). Finally, at a yet more specific level, three issues related to citizen participation are discussed, namely the lack of education of the population to the participatory smart city (i.e. smart cities adhering to the participative orientation), the difficulty for citizens to make use of the data necessary to support an informed participation, and the entry barrier of current participation methods (Section 2.3). These three barriers to citizen participation frame the problem statement of this thesis.

2.1 "But First of All, What Is a Smart City?"

During the 19th century, the proportion of citizens moving to urban areas started to increase steadily faster. Indeed, in 2014, the United Nations estimated the proportion of citizens living in urban areas at 54% (United Nations, 2014). According to their projections, this number will rise to 66% by 2050. This phenomenon is directly related to a change in demography, namely the increase in the world population, which followed the same exponential evolution. It also answers to a major change in economy, which occurred when the world population was at the start of its exponential growth. At this time, the Industrial Revolution took place, and the secondary sector became rapidly the most prominent and employed a large part of the population. These industries, located in urban areas, drove in citizens seeking employment.

The intensified urbanization of the population has resulted in cities growing larger, inhabited by hundreds of thousands, even millions in some cases, of people.

Consequently, many challenges related to the daily life of citizens emerged (Caragliu and Del Bo, 2009). For example, how to efficiently manage the waste produced by the population? How to ensure that traffic in the city remains fluid despite the high concentration of inhabitants? In 2005, with the emergence of new technologies, the Clinton Foundation launched a call to the networking company Cisco Systems, funding research on the application of new technologies to solve these urban issues (Montes, 2020; Cavada et al., 2014). Cisco Systems was rapidly joined by other major technological companies such as IBM ans Siemens who saw an interest in entering this new market. Following these efforts, and especially the large-scale "Smarter Cities" initiative by IBM, the "smart city" term was popularized around 2008 (Praharaj and Han, 2019) and started drawing an increasing attention from academia, reuniting researchers from diverse disciplines (Lytras et al., 2021). Montes (2020) illustrates this well with the number of publications about smart cities, which rose from 93 in 2008 to 6,159 in 2018. The numbers reported by Dameri and Cocchia (2013) and Cocchia (2014) confirm this trend.

This intense research on smart cities resulted in the proposal of a plethora of smart city definitions (Ramaprasad et al., 2017; Dameri, 2013; Fernandez-Anez, 2016; Montes, 2020; Mkrtychev et al., 2018; Nam and Pardo, 2011; Praharaj and Han, 2019; Mohseni, 2020; Cavada et al., 2014; Abdi and Shahbazitabar, 2020; Albino et al., 2015; Cocchia, 2014), creating fuzziness around the very meaning of the concept, which has thus no clear definition (Dameri and Cocchia, 2013). To add to the confusion, the "smart city" term is often used interchangeably with other related terms such as "digital city" or "intelligent city", which carry their own meaning (Albino et al., 2015; Dameri and Cocchia, 2013; Montes, 2020; Nam and Pardo, 2011; Dameri, 2013). In addition to scholars, private companies and later governments have proposed their own definitions of the smart city. Although presenting similarities in some instances, the existing definitions differ by their scope and their focus.

The first smart city definitions stemmed from the aforementioned private companies and are strongly focused on technology (Albino et al., 2015). This is unsurprising since their core business in the context of smart cities is to market technological solutions toward governments with the promise of easier management and increased efficiency. For example, IBM (Palmisano, 2008) defines a smart city as "an instrumented, interconnected and intelligent city." This strong emphasis on technology in early smart city definitions is referred to as the **technological orientation** of smart cities.

It underwent strong criticism by scholars such as Hollands (2008) and Greenfield (2013). In particular, they criticized cities who implement the solutions put on the market by the major technological companies with the sole objective of acquiring the "smart" label to promote themselves (Ramaprasad et al., 2017), and advocate to involve citizens and to take their needs as starting point when attempting to solve the urban issues instead of acquiring generic turnkey solutions. The incarnation of their vision is referred to as the **participative orientation** of smart cities, or participatory smart cities. As a result, other conceptions of the smart city emerged, putting the emphasis on aspects such as the human capital, the involvement of citizens, and their quality of life, whereas the current definitions focused on implementing technology for efficiency and monitoring purposes. A well-recognized definition is provided by Caragliu et al. (2011), who state that "a city is smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance." In such definitions, technology constitutes a means to become a smart city instead of what defines the concept. Many local governments in Europe define a smart city along those lines, two major examples being the cities of Amsterdam and Barcelona (Capdevila and Zarlenga, 2015). On the other hand, the technological orientation seems more widely adopted in Asia. A comparison between China and European smart cities showed that the inclusion of citizens is much less common in Chinese smart cities, which focus on rapidly deploying technological infrastructure (Riva Sanseverino et al., 2018). In India, a recent survey showed that the most popular vision of the smart city among urban development professionals is "a city that uses digital technology and ICT to better manage urban infrastructure systems such as transport, water supply and solid waste management," thus referring to the sole technological conception of the smart city (Praharaj and Han, 2019).

The dichotomy between the technological and the participative vision of the smart city has been further discussed from several perspectives in the literature (Mora et al., 2019). One of these concerns the way smart city strategies are implemented. Two main approaches exist, namely top-down and bottom-up (Mora et al., 2019; Breuer et al., 2014; Capdevila and Zarlenga, 2015; Przeybilovicz et al., 2018). In a smart city context, these two approaches differ by the stakeholder who initiated the process. Typically, in a top-down approach, the government unilaterally decides to implement a technological solution provided by a vendor. Conversely, bottom-up initiatives are those that emerge from citizens. The top-down approach characterizes technology-led smart cities whereas advocates of the participative orientation tend to recommend the use of bottom-up approaches. However, these two approaches are not exclusive, and previous research argues that combining them can actually prove beneficial (Breuer et al., 2014; Capdevila and Zarlenga, 2015). Indeed, both approaches come with downsides. The danger of top-down approaches is to lean toward a situation where the interests of the private companies' marketing solutions are given priority over citizens' concerns (Mora et al., 2019; Capdevila and Zarlenga, 2015). The smart cities that followed this approach often failed to achieve the expected objectives due to their inability to take into account the specificities of their territory (Dameri, 2014). On the other hand, relying exclusively on bottom-up initiatives may result in a smart city lacking integration and long-term vision (Breuer et al., 2014; Capdevila and Zarlenga, 2015). An example of the beneficial combination of the top-down and bottom-up approach is the development of initiatives by the government to allow citizens to make their voices heard on the smart city projects it pushes. Such efforts are strongly recommended, and even deemed critical for the success of the smart city, by advocates of the participative orientation.

In a response to these numerous, and sometimes conflicting (Cavada et al., 2014), visions of the smart city, several studies endeavored to shed the light on the smart city concept by providing a review of the existing definitions. One of the best known is the review by Albino et al. (Albino et al., 2015), who illustrated the lack of universality in the concept definition by listing 23 definitions. Fernandez-Anez (2016) compared the smart city definitions proposed by academic institutions, governmental institutions, local governments, and private companies in terms of action fields, goals, and information technologies mentioned. They reported similarities between the definitions of academic and governmental institutions (e.g. prominence of the quality of life) as well as differences among these four stakeholders (e.g. less importance given to the integration of technologies in the definitions from local governments). Ramaprasad et al. (2017) mention that there are over 36 definitions of the smart city. Mohseni (2020) analyzed 47 definitions extracted from scientific papers and distinguish between definitions that imply a bottom-up model of governance, definitions considering solely technological aspects, and definitions emphasizing the benefits of smart cities. Based on (Albino et al., 2015), Montes (2020) contributed an updated review comprising 28 definitions.

Some authors, in addition to contributing a review of the smart city definitions, attempted to formulate their own definitions by federating the concerns extracted from the definitions they analyzed. For example, Dameri (2013) defines a smart city as "a well defined geographical area, in which high technologies such as ICT, logistic, energy production, and so on, cooperate to create benefits for citizens in terms of well being, inclusion and participation, environmental quality, intelligent development; it is governed by a well defined pool of subjects, able to state the rules and policy for the city government and development." Fernandez-Anez (2016) defines a smart city as "a system that enhances human and social capital wisely using and interacting with natural and economic resources via technology-based solutions and innovation to address public issues and efficiently achieve sustainable development and a high quality of life on the basis of a multi-stakeholder, municipally based partnership." Ramaprasad et al. (2017) followed an approach involving more formalism and proposed an ontology describing smart cities. In their ontological model, the *smart* component is subdivided into structures (e.g. systems), functions (e.g. monitoring), focuses (e.g. environment), and semiotics (e.g. data), and the city is defined by stakeholders (e.g. citizens) and outcomes (e.g. sustainability).

As a complement to the definitions, sets of dimensions describing the components of the smart city have been proposed. Some of the aforementioned reviews list existing dimension classifications as well (Albino et al., 2015; Montes, 2020). However, even though several different dimension sets have been proposed, there is a fairly strong consensus toward the six dimensions proposed by Giffinger and Gudrun (2010), namely smart mobility, smart economy, smart governance, smart people, smart living, and smart environment. They are represented in Figure 2.1, along with a brief overview of their respective scope. **Smart mobility** focuses on providing to citizens a safe, efficient, sustainable, and innovative transportation infrastructure. **Smart economy** consists in supporting activities that generate employment such as entrepreneurship and innovation, and in making the labor market more flexible. **Smart governance** concerns the relationship between the government and the citizens, which is reflected in the services provided to citizens, the degree of their involvement in decision-making, and the transparency of governmental processes.

Smart people relates to the human capital, that is, the level of qualification and creativity of the citizens and how they leverage them to get involved in the public life of the city. **Smart living** is often considered as the broadest dimension in terms of scope. It covers culture, tourism, the safety of citizens, and the healthcare services available to them. **Smart environment** concerns the environmental impact of the urban activities and focuses on the protection of the environment and the management of the resources. It is essential to note that strong links exist between these dimensions (Giovannella et al., 2014). For instance, an inefficient transportation system may cause road congestion (*mobility*), which can in turn lead to increased greenhouse gases emissions (*environment*) and negatively impact the health of citizens (*living*). Therefore, whereas relying on a dimensions set to break down the complexity of the smart city is convenient, treating them as isolated silos cannot ultimately lead to a successful smart city (Moss Kanter and Litow, 2009; Albino et al., 2015).

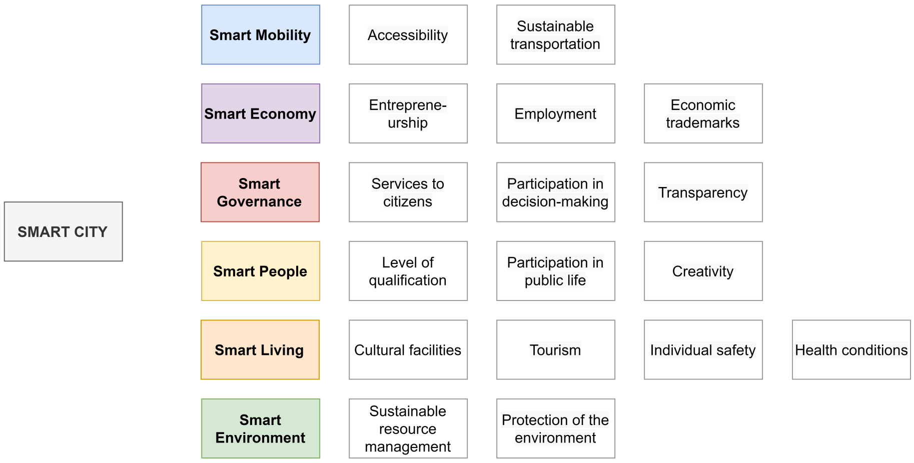


Figure 2.1: The six dimensions of the smart city following Giffinger and Gudrun (2010)

The vision of the smart city advocated for in this thesis is the participative orientation. In this line of thought and based on the definitions of Caragliu et al. (2011) and Chourabi et al. (2012), as well as the dimensions proposed by Giffinger and Gudrun (2010), the smart city is defined in this thesis as the following:

> A smart city is a city that provides innovative solutions, in collaboration with its citizens and with the support of technology, to solve the specific challenges of its territory in the domains of mobility, economy, governance, environment, living, and people.

The participation of citizens that defines the participative orientation is the cornerstone of this definition. It is the focus of the next section, which discusses the models defining citizen participation and the methods that implement it in practice.

2.2 Zooming Into the Participative Orientation of Smart Cities

Citizen participation can be defined as the process of including citizens in government decision-making. In the same line as Callahan (2007), political participation (i.e. voting) and citizen engagement in public life (i.e. referring to the smart people dimension from (Giffinger and Gudrun, 2010)) are excluded from this definition. Citizen participation is not a new concept, it was indeed discussed in literature much earlier than smart cities. However, the topic has strong connections with the participative orientation of smart cities and, and therefore benefits from the huge attention smart cities have been receiving in recent years from research and practice. In practice, it can be observed that an increasing number of governments are eager to engage in citizen participation efforts and effectively launch projects in this direction. Furthermore, the emergence of technologies provides new opportunities for developing innovative participation methods, which complement the long established traditional methods such as live meetings. In this section, the existing conceptual models describing participation and the methods that implement it in practice are discussed.

Citizen participation can take various different forms (Connor, 1988; Irvin and Stansbury, 2004; Macintosh, 2004; Przeybilovicz et al., 2020). It is often characterized as a spectrum where the decision power on an issue at hand is balanced between citizens and elected officials (Callahan, 2007). The influence of citizens can range from none (being informed of the decision taken by officials) to total (all decision power is delegated to citizens), with intermediate levels describing, for instance, situations where elected officials and citizens collaborate together toward a common agreement.

Several works have provided such spectrum conceptualizations of citizen participation. The most known is Arnstein's ladder of citizen participation (Arnstein, 1969), which was presented in 1969. It consists of an 8-tier ladder describing eight levels of participation (Figure 2.2). *Manipulation* and *therapy* refer to disguised forms of participation through which authorities aim to shape citizens' attitudes to gain their support. In Arnstein's ladder, they are also referred to as non-participation. *Informing* is the lowest level of participation. Citizens are kept informed by authorities through a one-way communication flow without opportunity to give feedback on the information. *Consultation* consists in giving to citizens the opportunity to give feedback, while not sharing the decision-making power with them. *Placation* denotes a higher participation level than consultation where citizens play a more active role in shaping the outcome of the participation process. However, the final decision still rests with the authority. These three levels of participation constitute tokenism, which describes participation in which citizens have an actual opportunity to share their views, but where the decision to take those into account rests with the government. Conversely, *partnership* denotes a form of participation in which the decision power is shared between citizens and the authority. On the next level, *delegated power*, the power is shared to such an extent that citizens hold a dominant position in the decision-making process. Making a step further in this regard leads to the ultimate level of participation, *citizen control*, where all decision power belongs to the citizens. These three levels are grouped under citizen power, which describes participation in which citizens have an actual opportunity to share their views and hold at least part of the decision power.

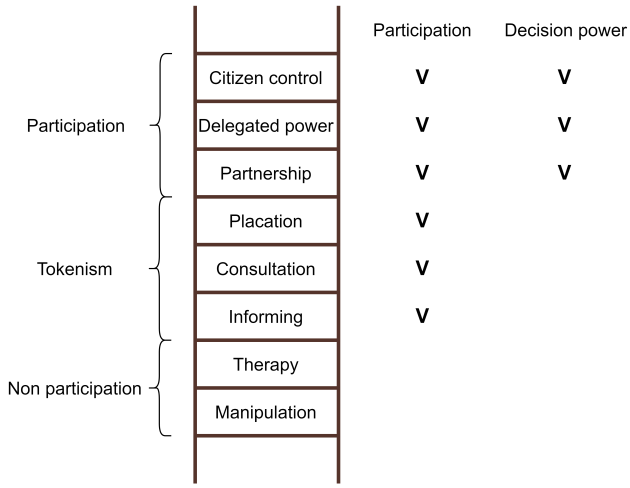


Figure 2.2: Arnstein's ladder of citizen participation (Arnstein, 1969)

Despite having been proposed more than 50 years ago, Arnstein's ladder of citizen participation is still the main reference in the field and is relied on by many scholars and practitioners, as evidenced by the amount of times her paper was cited. The main reason for this is most likely the simplicity of this model, which makes it convenient to use as analysis or reflection basis (Collins and Ison, 2006). However, this simple character has earned Arnstein's ladder criticism from several researchers. Furthermore, Arnstein herself stated that her ladder conceptualization has limitations and oversimplifies the reality of participation. For example, she claimed that her ladder could contain as many as 150 rungs instead of the 8 presented in order to describe the range of participation more accurately (Connor, 1988; Callahan, 2007).

Tritter and McCallum (2006) have researched the applicability of Arnstein's ladder for user engagement in health. They expressed three criticisms toward this conceptualization. The first set of criticisms relates to the oversimplication of Arnstein's model. Indeed, the 8 rungs constituting the ladder ignore several essential aspects of participation, such as the methods implemented for participation and the relationship between the objectives of the participation and those methods. Another neglected aspect, which Tritter and McCallum consider as "the most important missing rung in Arnstein's ladder," is the role of citizens in framing the problems. Arnstein's ladder also leaves out the diversity in people to involve in participation and does not balance user involvement intensity with the proportion of people who actually participate in each group. Indeed, a perfectly representative direct representation, necessary for citizen control to work, is unlikely to occur in practice, especially in the health context where groups of users cannot attend physical participation activities. The second criticism warns against negative effects of relying too heavily on Arnstein's ladder. The ladder structure suggests that participation efforts should unconditionally aim for the highest level, that is, citizen control. However, in practice, different participation forms are desirable in different contexts. Another danger of citizen control is that the decision may fit better the opinions of the participating individuals, and fail to meet the needs of those whose voice were underrepresented or not represented at all. Arnstein's ladder indeed leaves out the depth (i.e. stages of the participation where people are involved) and breadth (i.e. range of involved people) of participation. The third criticism questions the focus of Arnstein's ladder on the sole decision power. Tritter and McCallum explain that other types of user involvement exist that are not captured by Arnstein's ladder. They reject the metaphor of the ladder and suggest to conceptualize participation as a mosaic instead.

Collins and Ison (2006) built on the criticism by Tritter and McCallum and formulated additional concerns regarding Arnstein's ladder, also related to its oversimplified form. Arnstein's ladder only considers the balance of power between citizens and government but does not provide any insight on the process of participation, the feedback loops, nor the roles and responsibilities of those involved in the participation. They also deplore that Arnstein's ladder does not discuss how participation can be implemented as a collective process involving all concerned stakeholders when the issue is contested. This latter criticism was also expressed by Connor (1988), who proposed a new ladder of citizen participation considering this aspect. In his ladder, the final rung is the aim of participation, which is the prevention or the resolution of a controversy. The six lower rung are dedicated to activities aiming at reaching this goal, namely education, information feedback, consultation, joint planning, mediation, and litigation. The lower rung, education, refers to educating the public on the topic of the controversy. If this is not sufficient to prevent nor resolve the controversy, participation moves to the second rung, that is, information feedback, where citizens' views on the controversial proposal are collected. If the controversy cannot be diffused this way, the third rung, consultation, opens the discussion with citizens on alternatives to the controversial proposal. If it does not work, the fourth and fifth rung propose to involve additional stakeholders in the discussion. If neither joint planning nor mediation allow resolving the controversy, the situation is analyzed with a lawyer in the litigation rung.

Hurlbert and Gupta (2015) also criticized Arnstein's ladder for suggesting to unconditionally aim for citizen control and thus failing to take into account the circumstances of the participation. For example, they argue that structured problems may be best resolved with minimal participation whereas less structured problems may require multiple discussion loops. They propose an alternative model consisting in a split ladder of participation that takes these considerations into account (Figure 2.3).

The models presented in this section propose different levels of participation and give insights on which level is desirable in a given situation. However, whether participation is desirable altogether is another question. On that matter, two visions

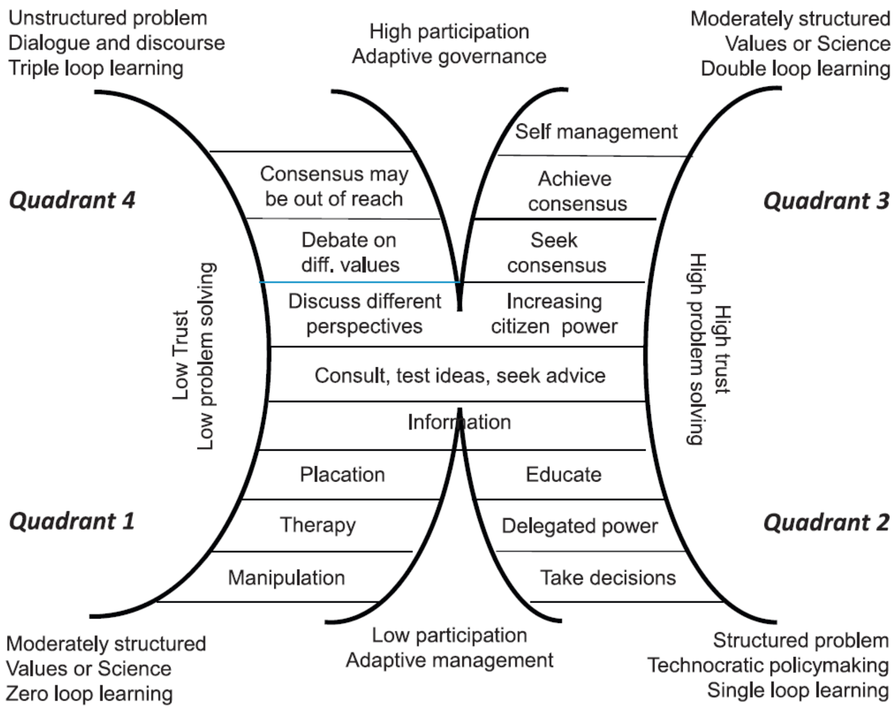


Figure 2.3: Split ladder of citizen participation proposed by Hurlbert and Gupta (2015)

diverge: an idealistic one, often solely theoretical, and an ultra-critical one, which emphasizes how participation processes are used to manipulate citizens (Blondiaux, 2017). Bacqué and Gauthier (2011) underline a third vision which comes as a middle-ground between the two aforementioned polarized ones. It recommends to focus on the challenges and conditions necessary for successful participation. This thesis inscribes itself in this vision by focusing on barriers to citizen participation and solutions to alleviate them.

Regarding the implementation of citizen participation, numerous methods exist and are used in practice. As discussed earlier, citizen participation existed long before smart cities. Probably one of the most ancient examples dates back to Ancient Greece, well-known for its agorae. A more recent yet prior to the craze around smart cities is town hall meetings (Lukensmeyer and Brigham, 2002), popular in the United States. Other smaller-scale methods based on live interaction such as interviews and workshops also have a long history of use.

The emergence of new technologies was a game-changer for citizen participation. Several scholars argued that while smart cities cannot focus solely on technology, technologies provide new opportunities and can be used as a means to empower citizens (Cugurullo, 2013; Kitchin, 2014). This led to new participation methods exploiting technologies, such as online platforms (Berntzen and Johannessen, 2016), coming to complement traditional ones. In a recent work, Simonofski et al. (2019b) proposed a list of eight citizen participation methods, namely interviews and group discussions, representation in project team, workshops, surveys, dedicated software, social media, innovation ecosystem, and prototyping, thus mixing traditional and technology-based methods. The impact of technology on participation processes was also discussed by Douay (2016), who proposed an 8-tier ladder of digital methods for participation in urban planning adapted from the ladder created by Arnstein (1969). *Information 1.0* refers to top-down information without communication opportunity such as a newsletter. *Information 2.0* is similar to Information 1.0 but offers the possibility to communicate through comments and likes, as on a social media platform. *Communication* consists in a dialogue with message exchange, achieved for example through a chat feature. *Consultation* is achieved through polls that can be implemented by an online voting platform. *Partnership* entails co-construction decision-making power sharing and can be achieved with a participatory budget platform. *Co-design* consists in collaboratively making online platforms and can take place through hackathons. *Co-deliberation* refers to the design of laws and consults citizens on bills. Finally, *deliberation* refers to debates and votes. One example of digital solution supporting the deliberation tier is the DemocracyOS platform, which is an open source platform defined as an "online space for deliberation and voting on political proposals" (DemocracyOS, 2014).

2.3 Barriers to Citizen Participation

As evidenced by the number of research projects funded on the topic and the number of participation initiatives launched by governments, citizen participation seems to be commonly accepted as desirable in smart cities. However, getting citizens to participate in a useful way is no easy feat. This was already a challenge in citizen participation prior to smart cities. Indeed, in 1998, King et al. (1998) have identified three sets of barriers to what they refer to as "authentic participation," which can be defined as participation in which citizens have a genuine impact on the outcome. These barriers were extracted from discussions with public servants and citizens. First, barriers related to life in contemporary society refer to the busy schedule citizens have to deal with day-to-day. They have to balance work and family and are often left with little time available to participate. Furthermore, King et al. explain that social interactions have changed significantly compared to several decades ago. Citizens from the same neighborhoods which used to form tight communities in the past do not talk to each other anymore nowadays, which is detrimental to their engagement in participation dynamics. The second set of barriers concerns the administrative process. Citizens largely view participation as implemented in practice as a one-way flow of information, and feel that it is already too late to have an impact when they have the opportunity to participate. The third set of barriers addresses the techniques of participation used in practice, which present important limitations. Public hearings are characterized by a low attendance and a silent approval from the participants, citizen panels are biased in terms of composition, and surveys do not allow interaction between citizens and public servants. Based on these barriers, King et al. have formulated 29 recommendations for practice, giving insight on how to work with citizens and public servants to create conditions suitable for authentic participation. Ten years after King et al. (1998), Rai (2008) identified the excessive bureaucracy, the lack of trust (resulting in perceiving citizen participation as futile), the lack of time and practical constraints such as the timing of meetings, and the lack of awareness as barriers to citizen participation.

Citizen participation in the smart city is subjected to such barriers as well. Indeed, in a study on citizen participation through living labs, van der Wal (2021) identified citizens' lack of skills, the lack of time, the lack of trust, and the information asymmetry, which results in citizens having unrealistic expectations toward participation as barriers. In the following sections, three barriers to citizen participation are discussed in light with King et al.'s recommendations and with literature specific to each. The goal of this thesis is to demonstrate the opportunities provided by technology to alleviate these three barriers.

2.3.1 Lack of Education to the Participatory Smart City (Barrier 1)

The multiple definitions (Section 2.2) and the fuzzy political discourses (Basu, 2019) around the smart city concept make it hard to picture the role citizens can have in it (Mohseni, 2020). In participatory smart cities, citizens are expected to take on different roles including democratic participants (Simonofski et al., 2018a). This is problematic, as citizens cannot feel concerned by a concept they do not understand and in which their role is blurry. This issue is also a political transparency one because smart cities are increasingly included in territory development strategies, and therefore drive political decisions and consume public money. The need to clarify the participatory smart city concept is in line with the recommendations formulated by King et al. (1998):

> Teach citizens how to work within the system and to work with the system.
>
> Place more emphasis on civics and public participation in K-12 [...] as well as in higher education. Educate to participate.

Following King et al.'s recommendation to educate to participation at the K-12 level, the focus is put on a sub-group of the citizenry: the children. Previous studies have shown that the participation of children is important for the democratic vitality of a city (Hart, 1992, 2008; Hennig, 2014), and beneficial to their skills development and preparation for adult participation (Chawla, 2001; Checkoway, 2011). The UNICEF, through the child-friendly city concept (Riggio, 2002; van der Graaf, 2020), also calls for the participation of children in public issues as it is part of their rights.

Several smart city initiatives for children have been published, with aims such as well-being improvement (Garau and Annunziata, 2019) and creation of learning experiences (Rehm et al., 2014). However, these initiatives focus on how the smart city can provide services to children but not how children can be active actors within this paradigm. A few solutions allowing involvement of younger audiences can nonetheless be found in the literature (Hosio et al., 2012; Donert et al., 2019). However, such efforts remain scarce, and children are in practice left behind in smart city participation initiatives (van der Graaf, 2020), whereas a wide range of methods have been proposed for adult participation (Simonofski et al., 2017a; Pallot et al., 2010; Aham-Anyanwu and Li, 2015; Simonofski et al., 2020a).

Besides the lack of participation initiatives destined to children, another important aspect is to prepare them to actually participate. Indeed, the early preparation of children to participation is key for their involvement in decision-making (Riggio, 2002; van der Graaf, 2020), but also for adult participation in the smart city. The lack of preparation for participation, especially when performed online, can lead to a participation divide between sub-groups of the citizenry (Hargittai and Walejko, 2008). An essential part of this preparation is to introduce the fundamentals concepts, namely the smart city and citizen participation, to children. A similar idea is also advocated in the spatial citizenship literature, which emphasizes that spatial skills are an essential prerequisite for participation activities, as in many cases they involve working with geographical representations (Hennig et al., 2013). Several works focus on integrating these skills to secondary education to allow children to participate in these activities (Gryl and Jekel, 2012; Gryl, 2015). Regarding smart cities, despite education being considered a key component (Giffinger and Gudrun, 2010; Nam and Pardo, 2011; Washburn et al., 2009), efforts on the education of children focused either on increasing the digital literacy (Lombardi et al., 2012; Mahizhnan, 1999) or on using new technologies to support in-class teaching activities (Neirotti et al., 2014; Washburn et al., 2009), which would also in turn contribute to improve the students' digital literacy. One perspective of education that is missing in the literature is the education to the concept of participatory smart city and of its ins and outs for citizens. Therefore, the following research gap is formulated:

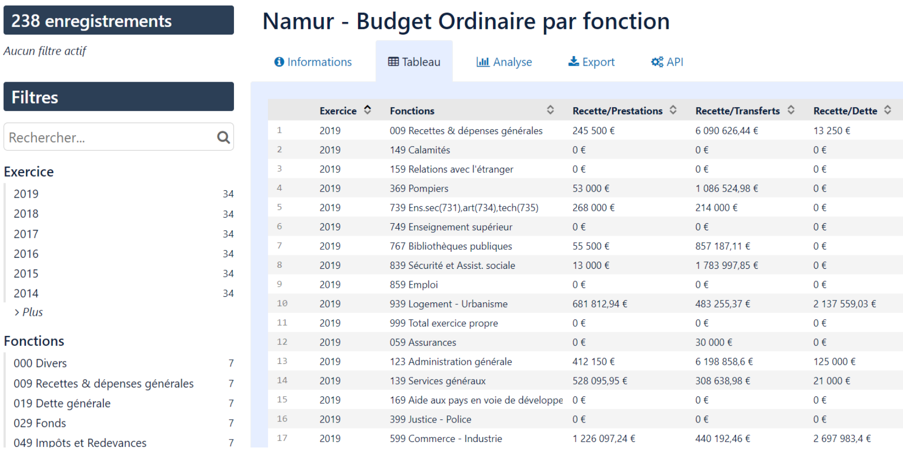
Research Gap 1: Lack of research on educating children to the participatory smart city.

2.3.2 Difficult Access to Usable Data (Barrier 2)

Since citizen participation consists in involving citizens into decision-making, it must start with citizens that are informed of the topic being discussed. Irvin and Stansbury (2004) go one step further and argue that in ideal conditions for participation, citizens should be able to understand the topic of discussion quickly and without the help of representatives. Therefore, citizens should have access to data about the city territory in order to understand the ins and outs of the decisions they participate in.

In the context of smart cities, an increasingly popular channel for governments to convey such data is open government data (OGD). OGD can be defined as interoperable data published on the Internet by a public organization (referred to as the publisher) to be freely reused and redistributed by anyone (referred to as the user) (Attard et al., 2015; Open Knowledge Foundation, 2015; Hossain et al., 2016). The current widespread publishing of such data finds its roots in several open data movements, the most important in the European context being the 2003 European Public Sector Information Directive, which renders mandatory for public authorities the publication of data regarding their activities.

The use of open data by various users such as organizations and citizens is expected to lead to several benefits, namely citizens engaged in policy-making, democratic accountability, self-empowerment of citizens, development of innovative products and services, and collective problem solving (Janssen et al., 2012). Driven by these promises, more and more city governments publish a wide range of datasets. The usual channel to publish OGD is through an online web portal. An example of such a portal is Open Health Data New York, which was found to increase transparency for researchers (Martin et al., 2015). Another example is the national Open Data Portal of Singapore that stimulated the creation of innovative e-services internally and by external partners (Chan, 2013). These portals can be developed at national, regional, or municipal levels of government (Kabanov et al., 2017). More specific to the Belgian context, the cities of Brussels, Namur, and Ghent have released 540, 150, and 116 datasets respectively. This data covers mobility (e.g. available parking spots), culture (e.g. events schedule), leisure (e.g. youth houses), environment (e.g. thermography), transparency information (e.g. allocated budgets), and many others. Figure 2.4 shows a transparency dataset, more specifically on budgets, that is available on the OGD portal of Namur.



	Exercice	Fonctions	Recette/Prestations	Recette/Transferts	Recette/Dette
1	2019	009 Recettes & dépenses générales	245 500 €	6 090 626,44 €	13 250 €
2	2019	149 Calamités	0 €	0 €	0 €
3	2019	159 Relations avec l'étranger	0 €	0 €	0 €
4	2019	369 Pompiers	53 000 €	1 086 524,98 €	0 €
5	2019	739 Ens.sec(731),art(734),tech(735)	268 000 €	214 000 €	0 €
6	2019	749 Enseignement supérieur	0 €	0 €	0 €
7	2019	767 Bibliothèques publiques	55 500 €	857 187,11 €	0 €
8	2019	839 Sécurité et Assist. sociale	13 000 €	1 783 997,85 €	0 €
9	2019	859 Emploi	0 €	0 €	0 €
10	2019	939 Logement - Urbanisme	681 812,94 €	483 255,37 €	2 137 559,03 €
11	2019	999 Total exercice propre	0 €	0 €	0 €
12	2019	059 Assurances	0 €	30 000 €	0 €
13	2019	123 Administration générale	412 150 €	6 198 858,6 €	125 000 €
14	2019	139 Services généraux	528 095,95 €	308 638,98 €	21 000 €
15	2019	169 Aide aux pays en voie de développe	0 €	0 €	0 €
16	2019	399 Justice - Police	0 €	0 €	0 €
17	2019	599 Commerce - Industrie	1 226 097,24 €	440 192,46 €	2 697 983,4 €

Figure 2.4: Dataset on budget allocation available on the OGD portal of the city of Namur (Belgium) - https://data.namur.be/pages/accueil/

Thus, OGD has a strong potential to support citizen participation. The transparency purpose it serves is indeed key to citizen participation (Johannessen and Berntzen, 2018). Furthermore, the wide range of issues it covers makes it likely that OGD would provide citizens with knowledge useful for their informed participation on any topic. However, the use of open data remains low in practice (Safarov et al., 2017) as OGD portals primarily provide OGD in machine-readable formats such as JSON and CSV, and the promises of open data are consequently not fully realized (Zuiderwijk et al., 2012). Yet, research shows that citizens are willing to engage in OGD for different reasons, depending on the context (Jurisch et al., 2015; Wirtz et al., 2018). For instance, Purwanto et al. (2020) found that citizens were motivated to engage in OGD to deal with societal issues and to contribute to a better government. However, OGD in its raw form does not necessarily lead to citizen participation (Simonofski et al., 2018a). Indeed, citizens that are not well-informed enough on the topic of participation experience a knowledge gap, which induces a need for information (Belkin and Vickery, 1985; Devadason and Lingam, 1997) rather than a need for raw data such as OGD. Data must be conveyed in a form suitable for citizens to make sense of, considering their skills. Davies and Bawa (2012) notes that contrary to early beliefs related to OGD, releasing raw OGD datasets is not sufficient to result in improved policy-making, and that "OGD feeds into decision making in more subtle (though not less significant) ways." Instead, OGD should be processed into more usable forms such as analyses and visualizations to initiate the dialogue that takes place in a decision-making process.

There are two approaches to tackle the gap between OGD provided as raw machine-readable datasets and usable data that citizens can use to derive information and fill their knowledge gap. The first is to present datasets in a human-readable way through tables and visualizations, made available on OGD portals directly or on external platforms (Chokki et al., 2021). The second is regarding citizens with significant programming or communication skills (e.g., developers or journalists) as intermediaries, or data transformers, who will develop services based on OGD for the population to allow citizens to benefit form OGD without needing to work with datasets in their raw format. These services thus use OGD as a source of information and can be used by all the citizens to satisfy their information needs. This is the approach conceptualized by Crusoe et al. (2020a). Therefore, when studying the use of open data by citizens, two types of users are generally considered, namely expert citizens (i.e. having high technical skills such as data analysis and programming) and lay citizens (i.e. not having any particular technical skill beyond the common use of consumer technologies).

Much of the previous research focuses on the exploitation of OGD on portals by experts (Crusoe and Ahlin, 2019), the features portals should have (Saez Martin et al., 2016), and the consequent challenges they may face (Beno et al., 2017). In an international comparison of 36 national portals, Saez Martin et al. (2016) analyzed OGD portals by structuring three aspects of requirements an ideal portal should have. The functional aspect refers to the utilities and functionalities of the portal through which the users can obtain and provide information (e.g. the data search techniques, the visualizations, and the feedback mechanisms). The semantic aspect refers to the arrangement of data on the portal to facilitate re-use (e.g. the level of metadata, the data format, the language of the portal). The content aspect refers to the website quality of the portal and how it provides the data (e.g. accuracy of data, number of datasets, availability of filters). Building on an extensive literature review, Crusoe and Ahlin (2019) structured the usage process of OGD portals by experts into four phases. First, the motivation phase refers to the user who needs to be aware and motivated to use OGD. In this phase, the user is trying to identify a reason to use OGD. In the search phase, the user is searching on the Internet, on OGD portals, and publishers' websites for promising data to use to reach the objectives of the motivation phase. In the access phase, the user has the goal to acquire promising data and transform it into usable data. In the use phase, the user has the objective to combine data and transform the new dataset into information, a product, or a service.

Several papers take the lay citizen perspective on OGD portal use. In his analysis of OGD portals, Lourenço (2015) concludes that typical portals such as "data.gov" do not support ordinary citizens and fail to reach their transparency and accountability goals. Several authors also argue that the notions of transparency and openness are related but not both enabled by current municipal OGD portals (Araújo et al., 2016). They argue for the development of "transparency portals", in line with OGD principles that are necessary to satisfy lay citizens (Corrêa et al., 2014). The development of OGD portals for lay citizens entails several specificities. In an analysis of the content and functionalities of portals, Thorsby et al. (2017) concluded that portals are at an early stage of development, have the same overall structure and interface, and need to improve their analysis and support functionalities to help citizens to make sense of the data. Indeed, Alexopoulos et al. (2014) mention that current platforms provide basic functionalities such as searching and downloading but fail to deliver value to users. Gebre and Morales (2020) explored the users' comments on OGD datasets and concluded that the descriptions found on the portal were too limited. Pinto et al. (2018) examined the categories of datasets on portals and found that the high number of categories for datasets can hinder the access to information by users. Safarov et al. (2017) mention that intermediary tools for data analysis and exploration are critical for lay citizens to use OGD. In this direction, Pussaar et al. (2018) proposed a platform co-designed with citizens allowing them to perform visual-based queries to make sense of the data and concluded that data should be nicely presented if citizens are expected to use it. Zuiderwijk et al. (2015) also recommend this support of end-users with demos, online courses, FAQs, or a helpdesk. Finally, Purwanto et al. (2020) identified several pre-conditions to increase citizens' intention to engage in OGD such as the perceived ease of engagement, the availability of feedback mechanisms, or the link with social media.

Previous research has identified some issues experienced by citizens and proposed OGD portal features that could resolve them. However, no work has described in detailed citizens' requirements toward OGD portals and evaluated them through a user study. This leads to formulating the following research gap:

Research Gap 2: No detailed list of citizens' requirements regarding OGD portals extracted from a user study.

2.3.3 Entry Barrier of Current Participation Methods (Barrier 3)

The current participation methods, that is, those listed by Simonofski et al. (2019b), come at the cost of an entry barrier. In other terms, citizens have to make a step forward to have the opportunity to participate (e.g. login to an online platform, attend a scheduled meeting), implying that it is challenging to attract citizens, let alone those who are not already engaged in participation. King et al. (1998) recommend the following to alleviate participation barriers:

> Go to where people are (lunch hour, child care centers, schools, churches, laundry facilities, electronic, etc.).
>
> Create opportunities for people to interact with each other.
>
> Change the way we meet and interact with each other and with citizens: many small meetings; [...] outside facilitators [...].

Technology provides opportunities to design participation methods that meet these recommendations. In particular, when linking cities and technology, one device that has been present in cities for many years comes to mind: the public display. Public displays are interfaces deployed in the public space to be accessible by any passerby (Vande Moere and Hill, 2012). They are the technological counterpart of paper posters and have therefore initially been used for advertising or event promoting purposes (Thiel, 2015). Recently, research efforts have been undertaken to study the potential of public displays in supporting citizen participation (Du et al., 2017). These devices possess qualities that are desirable in the context of citizen participation such as the ability to be interacted with by several citizens at a time, therefore fostering discussion (Brignull and Rogers, 2003), and their deployment in the urban space, thus being able to contextualize content that concerns its location (Vande Moere and Hill, 2012). Furthermore, public displays are exempt from the entry barrier limitation faced by the other participation methods. Indeed, citizens encounter public displays without explicitly looking for them, and can thus be offered a direct opportunity to participate. Thus, compared to other frequently used participation methods, public displays have proven able to reach a larger part of the population and thus collect a much greater quantity of citizen feedback (Goncalves et al., 2014; Johnson et al., 2016b).

Figure 2.5 presents four examples of public displays deployed for citizen participation purposes. The examples differ by their participation objectives, the way they are interacted with by citizens, and their location, and thus give a broad view of how public displays are used for citizen participation. Figure 2.5a presents Citizen Dialogue Kit, which enables organizations and bottom-up initiatives to show locally relevant data on a small-scale display and to collect citizens' opinion about it. Passerby citizens can vote by pushing on a button integrated to the display. The goal of the authors is to provide their solution in the form of a toolkit, thus allowing citizens to choose themselves the topic of the participation (Coenen et al., 2019a). Figure 2.5b shows Ubinion, which is a public displays system deployed in Oulu (Finland) for research purposes. It serves as a testbed for multiple research efforts and thus hosts multiple applications. One of them allows citizens to be informed and give feedback on a renovation project (Hosio et al., 2014a). The authors studied how different forms of feedback (writing free text, choosing a smiley on an ordinal scale) can be collected through their public display. Figure 2.5c illustrates MyPosition, which is a public display allowing citizens to share their opinion on a displayed question (Valkanova et al., 2014). Citizens can give an opinion ranging from strong disagreement to strong agreement through gesture interaction. The authors compare different conditions, preserving more or less the privacy of the vote. Figure 2.5d shows the Vote with your feet system described in (Steinberger et al., 2014). It consists of a public display deployed at a bus stop allowing passerby citizens to answer a displayed question. Citizens can cast their opinion by stepping on a *yes* or *no* pressure plate.

(a) Citizen Dialogue Kit (Coenen et al., 2019a)

(b) Ubinion (Hosio et al., 2014a)

(c) MyPosition (Valkanova et al., 2014)

(d) Vote with your feet (Steinberger et al., 2014)

Figure 2.5: Four public displays used for public participation reported in the literature. The examples differ by their participation objectives, the way they are interacted with by citizens, and their location, and thus give a broad view of how public displays are used for citizen participation.

However, deploying a public display that is able to successfully collect a large amount of citizen feedback is challenging. Indeed, citizens do not go to the public space with the specific goal of interacting with a public display, and in fact do not necessarily expect to encounter one. Therefore, in order to be effective as a citizen participation method, a public display needs to draw attention, and to convince citizens to interrupt their current activity to take time to interact with it. Previous research has dedicated a lot of attention to understanding factors that motivate or discourage citizens to interact with public displays. Well-known factors include the social context (Brignull and Rogers, 2003), display blindness (Müller et al., 2009) (i.e. passersby not noticing the display), and interaction blindness (Ojala et al., 2012) (i.e. passersby not realizing that the display is interactive). Another recurring factor is the interaction modality (i.e. the way citizens can interact with the public display). Deciding on the most suitable interaction modality is especially challenging. It can be a motivator to interaction by sparking curiosity (Hespanhol et al., 2015; Schiavo et al., 2013b) or, on the contrary, it can deter interaction by creating a social embarrassment feeling (Claes et al., 2017; Hespanhol et al., 2015) and it can cause fatigue or pain when it is not suited to the task (Bierz, 2006; Hosio et al., 2014a; Niiro et al., 2019).

Over the last years, several surveys have been published to study how users interact with public displays. Bierz (2006) conducted a survey on large displays and identified several technologies for interaction. He discussed the use of the laser pointer and the wand device as physical interactors, as well as the tracking of gaze, gestures, and body. As recommendations for further research, Bierz suggested to focus on interaction modalities that are natural for the users and cautioned against the fatigue caused by some physical interaction devices. Khan (2011) discussed four modalities for conveying and receiving information from a large display, namely speech, tracking, gestures, and haptics. As concluding remark, he underlined the high potential of smartphones as physical interactors with large displays. A 3-dimension interaction-centric taxonomy of public displays was proposed by Müller et al. (2010). The authors organized the surveyed systems according to the mental model (a public display can be perceived as a poster, a window, a mirror, or an overlay), the interaction modality, and the explicitness of the interaction. The authors underlined the importance of designing well-balanced public displays that are successful in drawing attention while not disrupting uninterested passersby. An extensive survey on large displays was carried by Ardito et al. (2015). Following a well-defined review protocol, the authors have collected 206 research works on interactive large displays from the ACM Digital Library and Google Scholar. The authors classified the articles according to a 5-dimension classification scheme: visualization technology, display setup, interaction modality, application purpose, and location. The results of their work indicate that projection-based displays are more frequent than monitors. As for the setup, vertical orientation is more frequently used, followed by the horizontal setup. Touch remains the most popular interaction modality, although body interaction is gaining interest. As for the application purpose, the large majority of the displays have a goal of productivity or entertainment. Finally, cities, universities and schools are becoming increasingly prominent locations for large displays, at the expense of in-office installations. Subsequently, the authors listed seven challenges for future research on large displays. Among others, they discussed collaboration between users, privacy of information, physical accessibility of displays, and evaluation.

Du et al. (2017) studied the use of public displays for public participation and have collected 36 ACM papers which publication year ranged from 2012 to 2016. They analyzed this body of research according to a multi-facet classification scheme. The analysis dimensions include the country where the research was conducted, the type of scientific contribution, the type of public display, whether the display serves several purposes, the shape of the display, the type of deployment space, the type of study (lab or field), and the level of participation addressed by the display. The authors found that public displays currently address low levels of participation and are challenging to evaluate. Furthermore they underlined the lack of non-empirical contributions (i.e. survey, theoretical, etc.) and the diversity gap in political contexts.

Previous surveys on public displays have emphasized the technological characteristics of displays. However, although such elements are essential to study, other important aspects such as the socio-demographics (Wijnhoven et al., 2015; Pak et al., 2017) of the displays' users, the impact of their participation (Arnstein, 1969), and their involvement in the development (Axelsson et al., 2010; Lindgren, 2014) and evaluation (de Róiste, 2013; Simonofski et al., 2018a) processes remain largely unexplored. Thus, a multi-perspective literature review of public displays and citizen participation is needed to take these important aspects into consideration. This need corresponds to the third research gap this thesis aims to fill, formulated as follows:

Research Gap 3: No complete picture on public displays and citizen participation.

2.3.4 Other Barriers

The barriers to citizen participation are not limited to the three discussed above. One repeatedly reported in literature is consultation fatigue, which refers to the loss of interest of the population for participation (Arnstein, 1969; Diduck and Sinclair, 2002; Hayward et al., 2004; Richards et al., 2004; Taylor et al., 2012), which may result from unsuccessful participation initiatives, differences of perception between citizens and government regarding the form participation should take (Simonofski et al., 2019b), or too numerous demands for participation. Another barrier is the lack of training and supporting resources provided by the public servants who must effectively implement participation. A third barrier is the monetary cost that is induced by participation (Callahan, 2007).

However, these barriers are left out of the scope of this thesis, which focuses on the citizen perspective and more specifically in making participation more accessible. Consultation fatigue is a cross-cutting concern related to the other barriers, and can therefore be addressed by the solutions proposed to those as well, especially by educating the public to the participatory smart city (Barrier 1). Regarding the lack of training and support for public servants, this issue was extensively discussed by Simonofski (2019), who proposed a framework for evaluating participation, a decision guide for designing participation strategies according to multiple factors, and a support tool allowing policy-makers to exploit social media and e-participation platforms data, among others. Other barriers on public servants side are listed by Tadili and Fasly (2019).

CHAPTER 3

Relevance for Practice

The previous chapter underlined the relevance of this thesis for research by elaborating on the research gaps it aims to fill. In this chapter, the relevance for practice side is addressed, through the lenses of the Belgian, and particularly the Walloon context. The research pertaining to this thesis was conducted in the context of the Wal-e-Cities research project consortium. This chapter details the objectives of the Wal-e-Cities project (Section 3.1) as well as challenges for practice in light of the Walloon context (Section 3.2).

3.1 The Wal-e-Cities Research Project

The Wal-e-Cities research project[1] is a 4-year joint research effort funded by the European Fund for Regional Development (50%) and the Walloon Region (50%). Its objective is to develop innovative citizen-oriented solutions in Wallonia, in the mobility, energy and environment, governance, smart living, economy, and connectivity domains. It takes the smart city approach to provide answers to the challenges brought up in the Background Chapter of this thesis, and adheres to the participative orientation. In doing so, it brings together four research and development innovation centers, four universities, and one research institute across six projects, each relating to one of the aforementioned domains. The research presented in this thesis was conducted for the mobility and smart living research projects, respectively referred to as MOB and LIV.

The **Wal-e-Cities MOB** project aims at researching low-cost hardware and software technologies for the capture, production, and processing of mobility information. Its course includes several activities, including (1) defining usage scenarii

[1] https://www.walecities.eu/

for the data in line with legal constraints such as the GDPR, (2) developing sensors and repurposing the existing urban technological infrastructure to collect mobility-related data, (3) exploiting the data through analyses, prediction models, and visualizations destined to experts and lay citizens, and (4) integrating the project deliverables. The deliverables are destined to be exploited inside the project as well as outside by Walloon private companies. The **Wal-e-Cities LIV** project aims at researching the elaboration of data collection devices, their interpretation, and citizen interaction, allowing the emergence of new services (e.g. public services, shops, leisure) improving the well-being of the population. It entails a chain of value centered around data collected from citizens, from the development of tools allowing their collection to their exploitation in interfaces destined to citizens, through technical challenges such as transmission and storage. Both projects favor an agile approach, with regular interactions with citizens, administrations, and/or private companies, depending on the activity, to iterate on the usage scenarii and the deliverables.

Figure 3.1 shows an overview of the Wal-e-Cities project with a focus on the three project activities this thesis contributes to. It must be noted that research conducted by other project partners also contributed to these activities. First, the data capture activity in the LIV project aims at developing techniques to collect data regarding citizens' quality of life and mode of consumption. Such data can be obtained in two complement forms, namely objective data collected through sensors, and subjective data collected by asking citizens directly. The value of this twofold data collection is that it makes it possible to confront objective data with perceptions. Second, the data exploitation activity in the LIV project aims at generating value from the collected data by monetizing it directly, conducting analyses, and proposing new services and adaptive interfaces destined to citizens. Third, the data visualization activity in the MOB project aims at developing interactive and efficient visualizations of mobility data destined to experts and lay citizens. On the expert side, visualizations are a support to their analysis and decision-making tasks. On the lay citizens side, visualizations are a channel to present mobility data in an understandable way to engage them in participation activities based on this data. A keystone concern of these three activities is citizen participation. In order to ensure consistency in the deliverables and the research approach (despite the work being spread across two research projects), the focus of the research was thus put on this aspect.

The Wal-e-Cities project carries a broad and integrated vision of the smart city and aims at putting around the same table people with different expertise. The project reunites four universities, four research and innovation centres, and one research institute. Their respective expertise covers a wide range of domains, including systems engineering, architecture, health, traffic simulation, interface and visualization design, and data processing. This way of working and the resulting interactions with such a diverse group of partners had a strong influence on the research conducted in this thesis. Indeed, while this thesis has a focus set on citizen participation, its contributions explore multiple directions and carry a multidisciplinary nature.

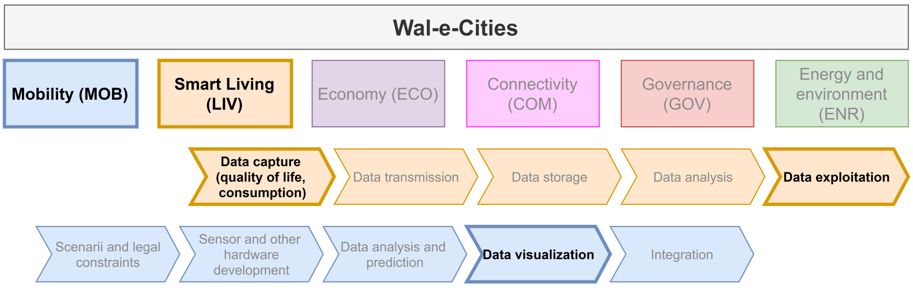


Figure 3.1: Overview of the Wal-e-Cities project with a focus on the three project activities this thesis contributes to

3.2 The Smart City Context of Wallonia

Similarly to what is observed in other countries across Europe and the rest of the world, many actions labeled as "smart city" initiatives emerged in Wallonia in the past years. An exhaustive presentation of them is beyond the scope of this thesis. This section proposes a brief and representative overview of them.

3.2.1 At the Municipal Level

Several Walloon cities are positioning themselves as smart cities and are launching projects in this perspective. One prominent example is Namur, the capital of the Walloon region, which has a strongly participative-oriented vision[2]. Indeed, the city of Namur frequently organizes citizen participation activities. Two recent examples are a participatory budget allocating 300,000 euros to citizens' projects[3] and a citizen consultation about the future downtown area developments[4]. In addition, Namur launched an open data platform[5] offering access to 150 datasets and hosts the TRAKK living lab[6]. According to the CitiVoice smart city evaluation framework developed by Simonofski et al. (2020c), these are positive indicators of an advanced citizen participation strategy. Furthermore, Namur is currently undertaking the construction of an innovation and experimentation center destined to the general public[7]. Other examples of Walloon smart cities are Liège and Mons, which both launched an online participation platform, host a living lab, and released open data.

The smart city vision adopted by Walloon cities has citizens in its center, and therefore corresponds to the participative orientation. Walloon cities are eager to implement participatory processes and already implement several of the participation methods listed by Simonofski et al. (2019b). However, the success of these

[2] https://www.namur.be/fr/ma-ville/ville-intelligente/namur-ville-intelligente

[3] https://www.namur.be/fr/ma-ville/citoyennete/participation/actualites-participation/budget-participatif-2020-appel-a-projets

[4] https://www.namur.be/fr/actualite/la-ville-de-namur-reflechit-a-l2019avenir-de-son-centre-ville-pourquoi-pas-avec-vous-1

[5] https://data.namur.be/pages/accueil/

[6] https://www.trakk.be/

[7] https://www.namur.be/fr/ma-ville/amenagement-du-territoire/pavillon-de-lamenagement-urbain

participation initiatives is sometimes limited, notably due to the inherent limits of these participation methods. In particular, the first set of barriers to authentic participation identified by King et al. (1998) (i.e. difficulty to attend physical participation events due to the other work and family related activities that have to fit within people's busy schedules) frequently verifies in practice. Remote participation through applications shows limits as well. For example, the FixMyStreet application which allows citizens from Brussels (Belgium) to participate by reporting incidents in the public space, fails to involve a set of users that is representative of the population (Pak et al., 2017). It is therefore essential to provide new and tested participation methods that can complement existing ones and compensate for their inherent limitations. This leads to the formulation of the following challenge for practice:

Challenge for Practice 1: Need to provide new and tested participation methods that can complement existing ones and compensate for their inherent limitations.

3.2.2 At the Provincial Level

At the provincial level, the main smart city drivers are the intermunicipal associations, which provide support to municipalities in their smart city projects and carry their own as well. One example is Idelux, which is a consortium of five intermunicipal associations. Its missions are to support the economic dynamism of Luxembourg province, finance companies, manage waste, preserve water, and carry out public projects on behalf of municipalities. In line with these missions, Idelux provides support to municipalities willing to engage in a smart city strategy. The municipalities from Luxembourg are essentially rural (approx. 280,000 inhabitants across 44 municipalities), and for the large majority do not have skilled staff dedicated to smart city projects. Idelux offers support in the elaboration of smart city strategies and redirects to smart solution providers, among others[8]. Another example is the BEP (Bureau Economique de la Province de Namur). Its missions notably include supporting the economic development, territorial development, and environment (i.e. including waste management). In the context of its territorial development mission, the BEP launched a smart city action program[9]. It provides support to municipalities from the Namur province willing to set up technological or participative tools in their territory. The BEP also hosts training sessions and workshops discussing the use of technology to solve their territorial issues. Finally, the BEP launched an open data platform[10], an online participation platform allowing citizens to share their ideas[11], and a crowdfunding platform where people can fund the ideas proposed by their fellow citizens[12].

[8] https://www.idelux.be/fr/smart-city-smart-ruralite.html?IDC=2728
[9] https://www.bep-developpement-territorial.be/smart-city/
[10] https://data.bep.be/
[11] http://g1idee.be/
[12] https://cilo.bep.be/

3.2.3 At the Regional Level

At the regional level, the ongoing Smart Region project[13] is providing a framework to foster the consistency and visibility of smart city projects implemented at the municipal level. It is conducted in the context of the Digital Wallonia strategy, which is the digital strategy designed by the Walloon government digital agency[14]. Its goal is to embed the smart city efforts of individual municipalities into an integrated vision across the region.

Other organizations such as innovation centers also provide support to municipalities across Wallonia in their projects. For example, Futurocité recently launched the "Ouvrir ma ville" (translated as: "Open my city") initiative, which guided 16 Walloon municipalities through the steps of publishing open data[15]. On the academic side, the Smart City Institute[16] is a research institute that provides methodological support to municipalities in the design and evaluation of their smart city projects. The e-Government Chair from the University of Namur offers, mainly to the public sector, an independent expertise on digital governance, and conducts consulting and scientific research works. Moreover, at the University of Namur as well, the SmartNGov network reunites over 40 researchers from the Namur Digital Institute that have an interest in topics related to the smart city and digital government.

Therefore, there seems to be a strong enthusiasm for open data publishing efforts in Belgium, as evidenced by the presence of multiple OGD portals covering the municipal, provincial, and regional government levels. However, as discussed in Section 2.3, the use of OGD remains low in practice, and the return on investment does not match the efforts. People in charge of publishing OGD in Namur reported the low use of the city portal as "frustrating" (Crusoe et al., 2020b). It is therefore necessary to understand whether the current way data is made available to citizens matches their needs and, where appropriate, to provide leads for improvement. This is the second challenge for practice, formulated as follows:

Challenge for Practice 2: OGD use by citizens remains low in practice, there is a need to determine whether current OGD portals are adapted to citizens' needs, and, if appropriate, to provide leads for improvement in order to increase their use.

Moreover, elements strongly related to smart cities are to be included in primary and secondary education across Wallonia. Indeed, while digital education is currently largely absent (Henry and Joris, 2016), an educational reform[17] is underway and plans to introduce digital and citizenship education as part of a polytechnic course to 5-15-year-old children. The content of the reform specifies the following regarding digital education:

> *[Translated from French]* In terms of knowledge and skills, the school will have to manage a number of evolutions and tensions related to the

[13] https://www.digitalwallonia.be/en/projects/smart-region#research
[14] https://www.adn.be/fr/home
[15] http://www.futurocite.be/ouvrirmaville/un-programme-en-5-etapes/
[16] https://www.smart-city.uliege.be/cms/c_4316710/en/smartcity
[17] http://www.enseignement.be/index.php?page=28280

> digital transition/revolution. It will be necessary to **encourage debate on the challenges of the digital world in order to promote the acculturation of students to the digital world** and make it not only a tool but also knowledge.

Concerning citizenship education, the following is stated:

> *[Translated from French]* **Preparing young people for the exercise of citizenship** is one of the essential missions of the school. It is a question of making the school a true institution of **democratic citizenship**. There is a broad agreement on the dual component of education for citizenship, consisting on the one hand in the exercise of citizenship and democracy within the school itself, and on the other hand in citizenship training that involves the acquisition of specific knowledge, skills, and attitudes.
>
> In this sense, the aim is to **develop interdisciplinary activities of active citizenship and within each course (equipping students to lead a debate)**, as well as the skills necessary for living together (self-assertion, acceptance of differences; finding one's place in a group, civic spirit, health prevention, mediation and conflict management; international solidarity, respect for the environment, etc.). The functioning of **participatory structures within the school** and the development of places that allow for debate and conflict resolution in the different moments of school life play a particularly important role.

Discussing smart cities with children in the context of the polytechnic course would serve both purposes. Indeed, the way smart city solutions are implemented in Belgium entails technology and participation of the citizens. Addressing the smart city concept with children would encourage them to develop critical thinking toward technology and citizen participation and to develop realistic expectations from them. However, as explained in Section 2.3, the concept of smart city remains fuzzy for the general public, which include primary and secondary teachers. There is therefore a need to develop tools assisting them in discussing the ins and outs of smart cities in their classes. This leads to formulation of the following challenge for practice:

Challenge for Practice 3: Upcoming educational reform, there is a need for tools assisting primary and secondary teachers in critically discussing technology and citizen participation in their classrooms.

Part II

Research Design

CHAPTER 4

RESEARCH QUESTIONS

The overall research objective of this thesis is to study how access to citizen participation in smart cities can be facilitated by alleviating barriers to participation. Due to the large scope of this objective, the focus was put on three barriers taking the citizen perspective. They were selected from an analysis of the literature 2.3 and of the Walloon context 3.2.

Each of these barriers addresses a specific concern of access to participation in smart cities. Therefore, the research objective of this thesis was refined into one research question (RQ) per barrier. Figure 4.1 illustrates the mapping between the barriers, the research gaps, the challenges for practice, and the research questions.

Barrier 1 concerns the **awareness of participation**. In order to participate in the smart city, citizens first need to understand its meaning and implications, which include citizen participation. Barrier 1 is associated with Research Gap 1 and Challenge for Practice 3. The research question focusing on the alleviation of Barrier 1 is formulated as follows:

- Research Question 1: How to educate children to the participatory smart city in a school setting?

There is no literature on introducing the participatory smart city to children. Therefore, in addition to developing a solution for introducing this concept, it is essential to identify which elements children consider as important for such a solution. These insights would be useful for other researchers willing to engage in developing smart city introductory activities of their own or to build on the contributions of this thesis. Therefore, the two following research sub-questions emerge from RQ1:

- Research Question 1a: What elements do children consider as important in an introduction to the participatory smart city?

- Research Question 1b: How to educate children to the participatory smart city in a way that fits the school setting constraints and that incorporates the elements important to them?

Once citizens are sensitized to participation, they must be provided with knowledge necessary to deeply understand the topic of participation. Therefore, Barrier 2 focuses on the **prerequisites to participation**, more specifically in terms of accessing data necessary to construct this understanding of the topic. Barrier 2 is associated with Research Gap 2 and Challenge for Practice 2. The research question addressing Barrier 2 is :

- Research Question 2: To what extent do current OGD portals meet citizens' requirements?

This research question entails two issues. The first one directly answers Research Gap 1 and consists in identifying what are the requirements of citizens. The second is subsequent and concerns the improvements that can be made to current OGD portals resulting from the identified requirements. Therefore, RQ2 is refined into the following research sub-questions:

- Research Question 2a: What are citizens' requirements toward OGD portals?
- Research Question 2b: How can current OGD portals be improved to better meet citizens' requirements?

Finally, once citizens are sensitized to participation and have the necessary background to participate meaningfully, concrete opportunities must be provided to them to do so. Thus, the focus of Barrier 3 is on the **methods of participation**. Barrier 3 is associated with Research Gap 3 and Challenge for Practice 1. The research question focusing on Barrier 3 is:

- Research Question 3: What citizen participation purposes can public displays efficiently serve?

In order to provide a complete picture of the intersection between public displays an citizen participation, RQ3 was addressed from two angles: how citizens participate in the development of public displays (i.e. public displays *by* citizen participation), and how public displays foster citizen participation on urban issues (i.e. public displays *for* citizen participation). This results in two research sub-questions being formulated:

- Research Question 3a: How can citizens be involved in the development of public displays?
- Research Question 3b: How can public displays be used as participation method?

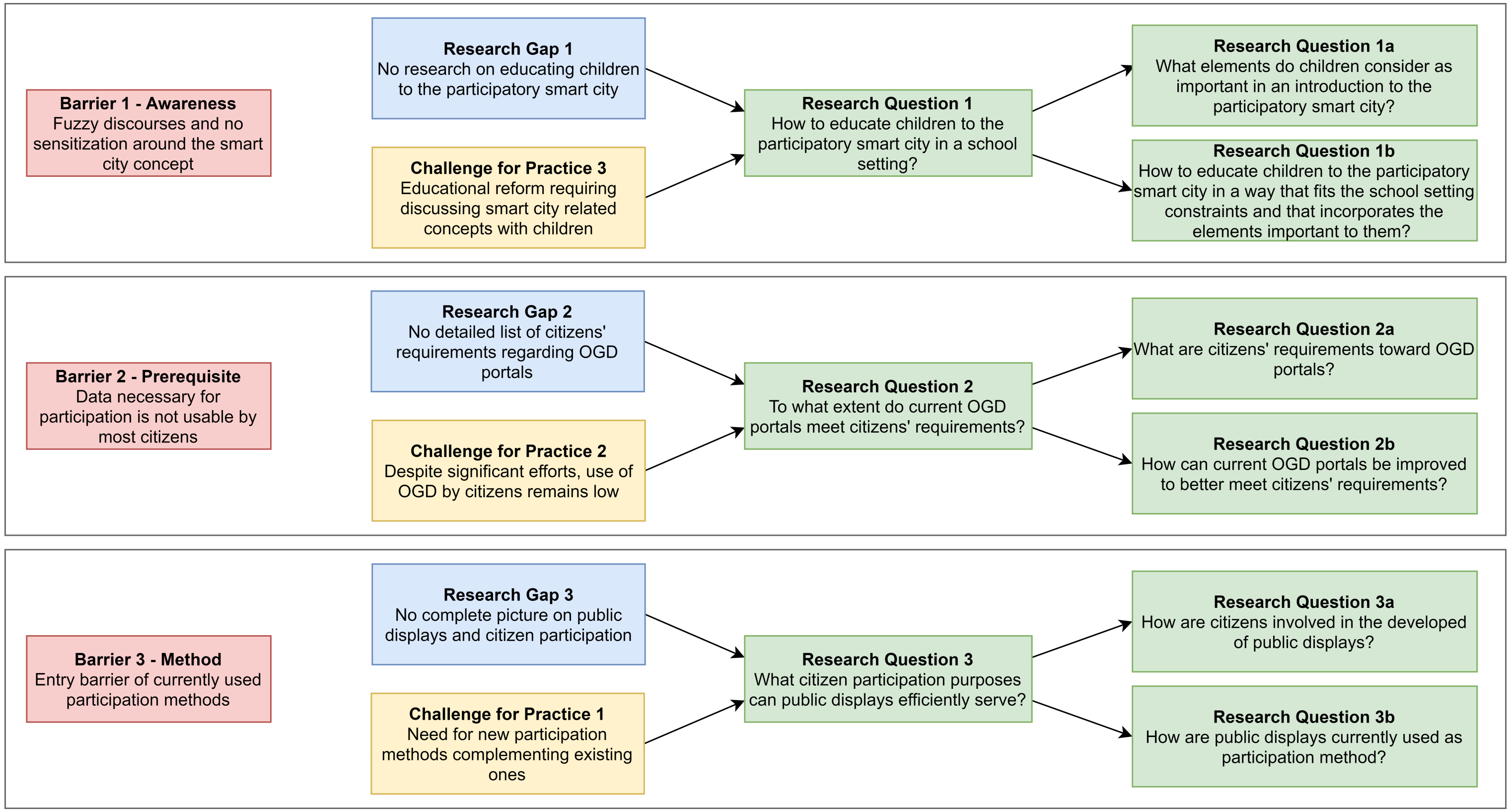


Figure 4.1: Mapping between the barriers, the research gaps, the challenges for practice, and the research questions

Alleviating these three barriers can be viewed as a staged process to facilitate access to participation (Figure 4.2). Indeed, they are all essential to reach the final objective and follow a specific arrangement. Implementing methods without citizens being sensitized to participation (i.e. stair step 1 missing) would lead in biased participation, involving only those who are already engaged. On the other hand, merely sensitizing to participation without implementing concrete participation methods (i.e. stair step 3 missing) would be frustrating for citizens and ultimately degrade their vision of participation. In both cases, the objective of meaningful participation cannot be met.

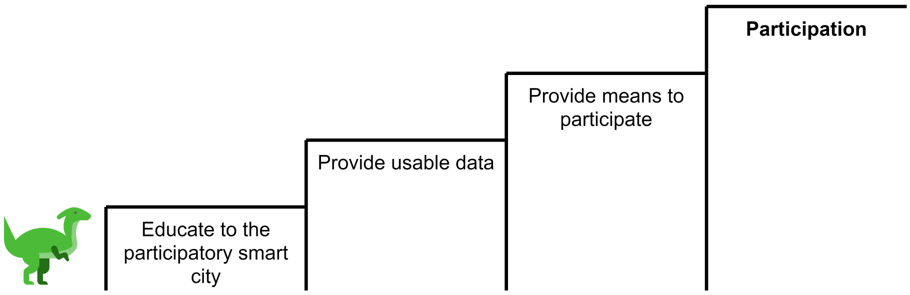


Figure 4.2: Staircase view of the alleviation of the three barriers to citizen participation

CHAPTER 5

METHODOLOGY

This chapter presents the research approach followed to address the research questions. Section 5.1 presents the overarching approach that is common to the three research questions. Section 5.2 details how this overarching approach was implemented for each research question and the specific methods involved. This chapter gives a high-level view of the research design. Details concerning the collection and analysis of the data pertaining to each contribution are provided in their relative sections in the Result Part. Data collection instruments are provided in full in the appendices of this thesis.

5.1 Overarching Methodology

Each of the three barriers, and thus each of the three research questions was addressed independently from the others. This approach was preferred because each one tackles a specific concern of access to participation. However, while conducting the research, interesting relationships between the barriers were identified and are discussed in the final part of this thesis as leads for further research in Chapter 10.

The overarching approach was common for the three research questions. It can be structured around the following steps (Figure 5.1). First, a barrier is identified from the research and practice dual perspective. Its exploration results in a first contribution (a). Second, the findings from this contribution define specific leads for further research on tackling the barrier (b). Specific contributions focus on only one lead informed by the barrier exploration contribution, and thus have a more restricted scope. Given the limited timespan of the research activities pertaining to this thesis, only some of these leads could be addressed and resulted in specific contributions (c). The others are deferred to future work (d) and are discussed in the Future Work chapter. The exploration and specific works contribute to the alleviation of their respective barrier (e).

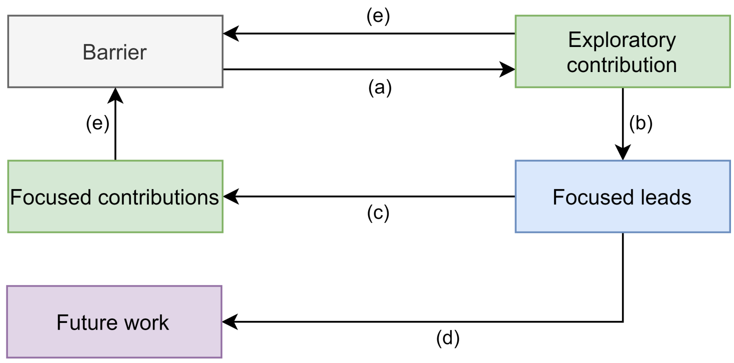


Figure 5.1: Overarching methodology applied for each research question

5.2 Research Methods

5.2.1 Research Design for Research Question 1

The methodology chosen to address RQ1 is design science research (Hevner et al., 2004). It is a well-established methodology in the Information Systems field which aims at developing an artefact that has a demonstrated efficiency to answer a practical problem. This approach is conceptualized in a framework comprising three entities (Figure 5.2). The **environment** describes the space into which the problem must be solved and is composed of people, organizations, and technologies used by these people and organizations. The **research** describes the development activities of the artefact, which is iteratively evaluated and refined. The **knowledge base** consists of the foundations and methodologies that can be applied to the development of the artifact. Design science research is articulated into three cycles. The design cycle consists in the development and refinement of the artifact, the relevance cycle refers to the application of the artifact in the environment to solve the problem, and the rigor cycle leverages the knowledge base to develop the artifact and adds to the knowledge base from the evaluation results. The iterativeness of design science research suits well the context of RQ1. Indeed, there are no other solutions reported in the literature to educate children to the participatory smart city, an iterative development of the solution is therefore essential.

Using foundations from the smart city and education literature, and taking into account the constraints of the environment (i.e. a secondary school classroom), a workshop for introducing the participatory smart city was developed and validated through experiments with 299 children. The impact of the workshop was assessed through an experiment, more specifically a one-group pre-test-post-test (Grieve, 1981; Dimitrov and Rumrill Jr, 2003) questionnaire design. The feedback from the evaluation suggested several leads for adapting the workshop, namely improving

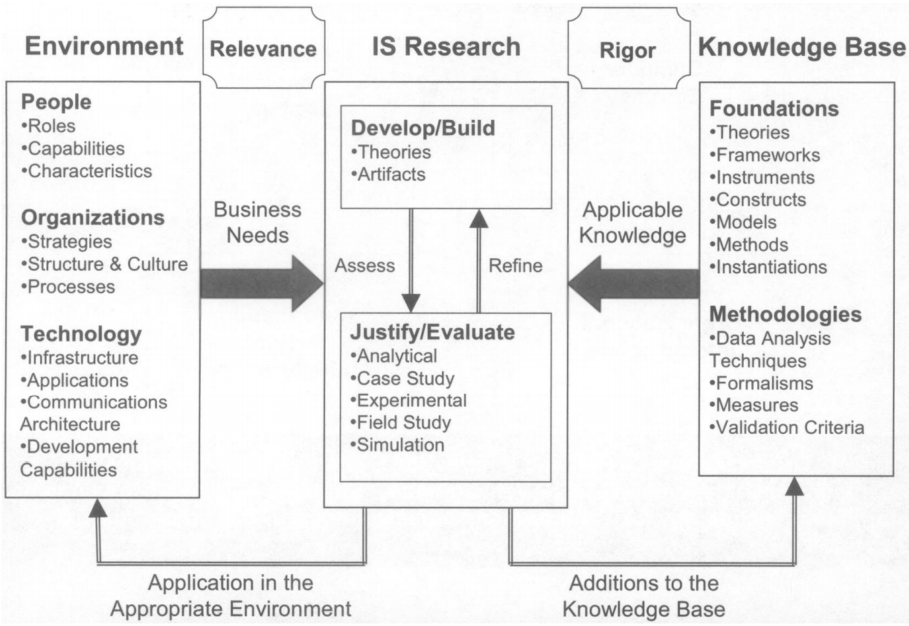


Figure 5.2: Design science research framework Hevner et al. (2004)

the interactivity, injecting real-world data, and adapting the workshop for adult audiences. The lack of interactivity was investigated further in this thesis, and a functional prototype of a tangible interaction table was developed. It constitutes the specific contribution of RQ1. The two other leads were deferred to future work. Figure 5.3 shows how the overarching methodological approach was implemented for RQ1.

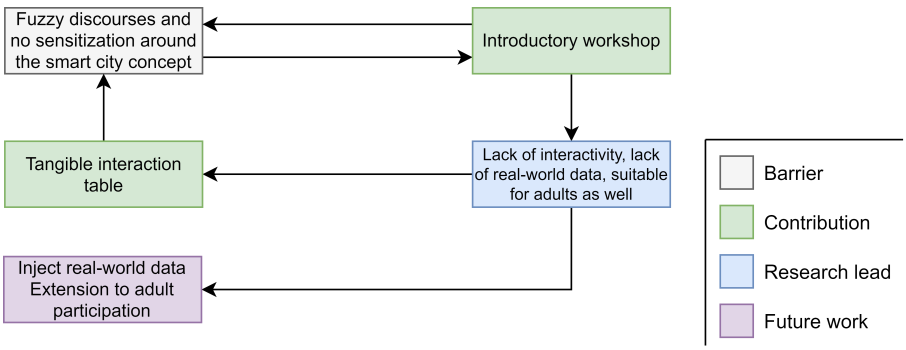


Figure 5.3: Methodology for addressing RQ1

5.2.2 Research Design for Research Question 2

The first step in investigating RQ2 was to understand the difficulties citizens face when using OGD portals. As explained earlier, two types of citizen users are generally distinguished in the OGD literature, namely expert citizens and lay citizens. In order to take into account the differences between these two user groups, difficulties experienced when using an OGD portal were studied separately for each. As emphasized in the Background Chapter, there are more theoretical foundations on OGD portal use by expert citizens than by lay citizens. A mixed-methods approach was chosen for the requirements elicitation of expert users. This consisted in collecting both quantitative and qualitative data to study a phenomenon. Johnson et al. (2007) argue that a combination of methods allows having informative, complete, balanced, and useful research results. It is relevant for several purposes (Recker, 2012; Venkatesh et al., 2013), and was used in particular for development (i.e. use data collected using one method to fuel the data collection instrument of another method) and expansion (i.e. use the data from one method to deepen the findings of another method). Since there is an existing framework on which data collection can be based (Crusoe and Ahlin, 2019), an explanatory sequential design (Figure 5.4) was preferred (Creswell and Clark, 2017). A questionnaire based on this framework was first administered, and the responses were analyzed to determine the most relevant elements to discuss in follow-up interviews (*development*) in order to collect deeper insights (*expansion*). On the lay citizen side, a mono-method qualitative approach was chosen, with data being collected through interviews. Interviews can be used to obtain rich exploratory data (Recker, 2012), which suits well the objective of collecting citizens' requirements on a phenomenon they do not know much about with few theoretical foundations available in the literature.

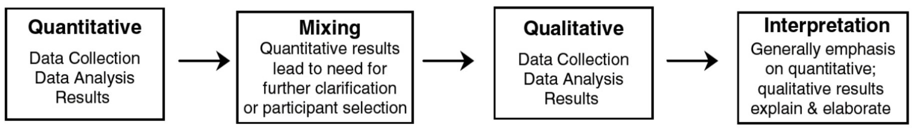


Figure 5.4: Mixed-methods explanatory sequential design (Plano Clark et al., 2008)

The findings from the lay citizens' requirements elicitation show that data visualizations are needed on OGD portals. Therefore, this direction was explored further through a literature review of visualizations of mobility data. Mobility was chosen as it is a theme of high interest for Belgian citizens (Pouleur et al., 2018; Lago et al., 2019) and because mobility data is commonly published on OGD portals. In order to obtain the most complete coverage as possible, and to report an objective selection of works, the well-established systematic literature review methodology (Kitchenham and Charters, 2007) (Figure 5.5) was chosen, combined with a snowball analysis (Lecy and Beatty, 2012) to improve the results as recommended in the literature (Mourão et al., 2020). The systematic literature review methodology provides guidelines on selecting and analyzing research works based on specific research questions. The findings also showed that the attractiveness of the portals should be improved for lay citizens. In the Future Work, we discuss how gamification could be applied to OGD portals to solve this issue. Figure 5.6 shows how the overarching methodological approach was implemented for RQ2.

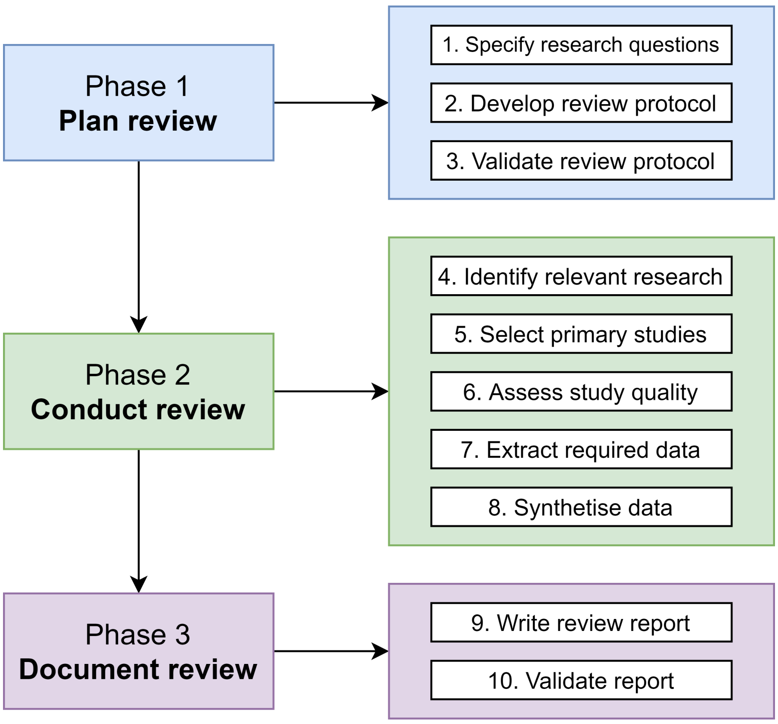


Figure 5.5: Systematic literature review methodology (Brereton et al., 2007)

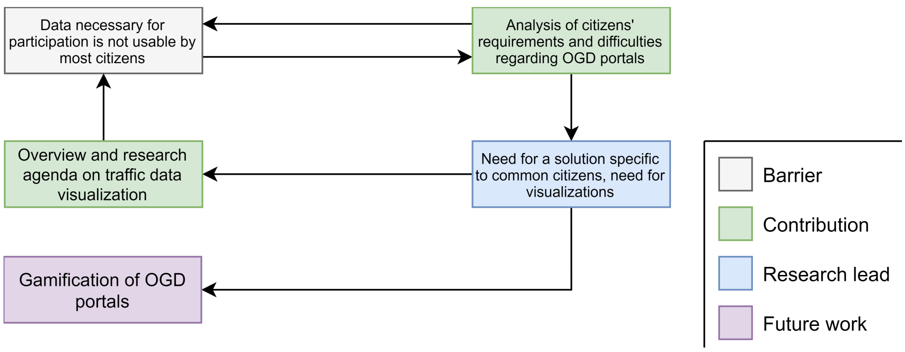


Figure 5.6: Methodology for addressing RQ2

5.2.3 Research Design for Research Question 3

RQ3 covers an already established research field and answers to the need of a complete picture of this field. Therefore, a literature review was performed on the related research works, relying on the systematic literature review methodology and the snowball literature search for the same reasons as in RQ2. In addition to a detailed overview, the analysis of the selected works allowed defining a research agenda, elaborating on four valuable research avenues for public displays and citizen participation. Two of the directions from the research agenda were investigated further in this thesis and led to two specific contributions. First, a process model describing interface adaptation in public displays was theorized from the empirical studies surveyed in the literature review. Second, in order to help developers of public displays involve citizens in an optimal way, a survey research was conducted via a questionnaire to determine the development stages in which citizens would prefer to participate, and the methods they prefer for participating. The quantitative approach was preferred in order to collect data from a large number of citizens. Figure 5.7 shows how the overarching methodological approach was implemented for RQ3.

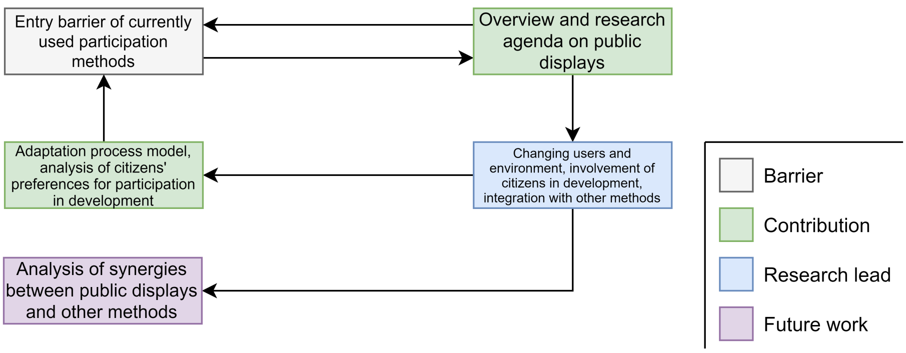


Figure 5.7: Methodology for addressing RQ3

Part III

Results

CHAPTER 6

TACKLING BARRIER 1: EDUCATING CHILDREN TO THE SMART CITY

6.1 General Introduction

This chapter presents the contributions developed to address the first barrier, that is, the lack of education to the participatory smart city. Although there are many possible lines of attack to address this issue, we have decided to focus on children, and more specifically children from 12 years old. This is motivated by the calls from literature to educate K-12 children (i.e. children enrolled in an education program up to the 12th grade, which corresponds to the end of secondary education) to civic participation (King et al., 1998) and the call of the UNICEF for the participation of children in public issues, mentioned in Chapter 2 (Research Gap 1). The second motivation is the upcoming educational reform in Wallonia, calling for digital and citizenship education destined to 5-15-year-old children, detailed in Chapter 3 (Challenge for Practice 3).

Research Gap 1: Lack of research on educating children to the participatory smart city.
Challenge for Practice 3: Upcoming educational reform, there is a need for tools assisting primary and secondary teachers in critically discussing technology and citizen participation in their classrooms.

The approach we chose to address Research Gap 1, implying to reach children, and to answer Challenge for Practice 3, implying to provide tools for teachers, is to propose a workshop introducing the participatory smart city that can be given as an in-class activity. Although this adds the constraint of fitting the school context, this approach is the most suitable to provide a realistic answer to Challenge for Practice 3 and to reach a high number of children, ensuring a thorough validation of the contributions.

We have designed and tested several formats of the workshop and we have asked children their opinion about their positive and negative aspects. This allowed understanding which aspects are important to include and to avoid when developing such a workshop. The encouraging results of the workshop evaluation suggest that one of the formats we developed can indeed be used to efficiently introduce the participatory smart city to children. Nonetheless, the evaluations revealed that interactive visualizations would be helpful to fuel the discussions children have during the workshop. We developed an interactive version of the workshop relying on a tangible table with the goal of answering this need while strengthening the playful aspect of the workshop.

6.1.1 Publications

The content of this chapter is based on the following peer-reviewed scientific publications:

Anthony Simonofski, Antoine Clarinval, Julie Henry, and Anne Smal. C'est quoi une ville intelligente? comment l'expliquera mes éleves de maniere ludique. In **Proceedings of Educode**, pages 1–9, 2018b. Available at https://school-it.info.unamur.be/wp-content/uploads/2018/09/SmartCity-compressed.pdf

- This article presents the motivation for the creation of the workshop introducing the participatory smart city to children. It describes the conduct of the workshop into details as well as the necessary equipment.

Anthony Simonofski, Bruno Dumas, and Antoine Clarinval. Engaging children in the smart city: A participatory design workshop. In **Proceedings of the International Workshop on Education through Advanced Software Engineering and Artificial Intelligence**, pages 1–4. Association for Computing Machinery, 2019a

- This article presents the preliminary evaluation of the workshop. it was conducted with one class of 25 children enrolled in the second year of general secondary education. It showed promising results on the engagement of children as well as an evolution in their understanding of the smart city. This allowed moving to the large-scale evaluation after minor changes to the conduct.

Antoine Clarinval, Anthony Simonofski, Julie Henry, Benoît Vanderose, and Bruno Dumas. Introducing the smart city to children: Lessons learned from practical workshops in classes. **Journal of Urban Technology**, 2021b. Under review

- This article presents the large-scale evaluation of the workshop. Four different formats were tested with 274 additional children and data was collected before and after the workshop to assess its impact on the children's understanding of the participatory smart city. It showed success in improving the children's understanding of the smart city concept (citizen participation was associated with the smart city much more frequently after the workshop). It also highlighted the desirable and unwanted elements of the workshop.

Antoine Clarinval, Caroline Deremiens, Thomas Dardenne, and Bruno Dumas. Introducing the smart city to children with a tangible interaction table. In **Adjunct Proceedings of the French-Speaking Conference on Human Computer Interaction**, pages 1–8, 2021a

- This article presents a new version of the workshop supported by a tangible interaction table. The table is designed to provide children with visual aids supporting the debates throughout the workshop and to strengthen its playful aspect.

6.1.2 Outline

This chapter is structured as follows. Section 6.2 details the methodology followed for developing the workshop and for collecting and analyzing the data related to its evaluation. The conduct of the workshop is described in Section 6.3. Section 6.4 presents the findings of the evaluation of the workshop, which was first done preliminarily with one class of 25 children and then on a larger scale with 274 additional children. The lessons learned from this evaluation and improvement leads of the workshop are discussed in Section 6.5. One of these leads, namely improving the workshop with a tangible interaction table, was pursued and resulted in the contribution presented in Section 6.6. Section 6.7 discusses the limitations of the contributions. Finally, Section 6.8 closes the chapter by summarizing its contributions and discussing how they contribute to its research questions of interest.

6.2 Methodology

6.2.1 Workshop Development

In order to develop the workshop, we have worked through several cycles following the best practices of design science (Von Alan et al., 2004) as shown in Figure 6.1. Design science is an iterative research methodology that consists in creating an output linked with technology to serve human purpose. This output is in our case a workshop. First, we performed an initial literature review to find ideas about the structure of the workshop. Thanks to this review, we relied on participatory design principles as this method is helpful to include children in planning processes (Hennig and Vogler, 2016; Fails et al., 2013). Moreover, we also relied on future workshop techniques as they enable non-experts to imagine innovative solutions to solve issues in urban planning (Jungk and Müllert, 1987). This initial literature review also constituted the rigor cycle as we identified research gaps in the knowledge base to be answered by this workshop. Second, having an initial version of the workshop based on these sources and knowledge from the smart city literature, we improved it in close collaboration with two researchers expert in digital education. One has experience with training teachers to introduce programming to children, and both have experience with teaching programming to children. Third, we were able to test the workshop through one first in-school session that enabled us to improve it based on the class experience and the children's and teacher's feedback. Finally, we got early feedback on the workshop content and the results of this session from conferences on digital education (Educode 2018[1], Ludovia 2019[2], EIAH 2019[3], and SETT 2019[4]). The feedback was provided by teachers (mostly from secondary schools) and researchers in digital education working in Belgium, France, and Switzerland, and by public servants as well. These presentations and the evaluations of the workshop also contributed to the relevance cycle. Indeed, we ensured that the workshop contributes to its environment and answers the educational needs of children as well as the objectives of the teachers.

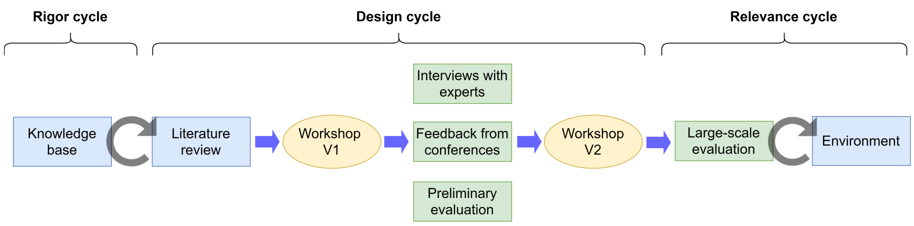


Figure 6.1: Methodology followed for the development of the workshop, following design science research principles.

6.2.2 Data Collection

In order to test the workshop in real-life conditions, we decided to perform field experiments in classrooms following the best practices of educational research (Lindquist, 1953; Cobb et al., 2003; Creswell, 2013). Following the children and youth categories presented in (Hennig, 2019), we have set our target group to teenagers (i.e. 13-18 years old), as they are characterized by a high priority given to social involvement. Participating schools were recruited on voluntary basis based on the network of schools present in the School-IT project[5]. Our call for participation received interest mainly from teachers teaching in first, second, and third secondary, that is, children aged 12 to 14. In response to these participation requests, we adapted our target group accordingly and included 12-year-old children. All the workshops were given by two researchers with the presence of the respective class teacher. Four workshops were given to classes visiting the campus in the context of an event hosted by the University of Namur. For the other workshops, the researchers went to the children's school and the session was given in their classroom. In the selection of participants, no restriction was made on the education type, and the three existing in Belgian education were considered. *General education* refers to the conventional education path that prepares pupils for graduate studies. *Specialized education* allows a pupil to evolve at his or her own pace, thanks to a pedagogical guidance that allows for individualization of the education. This type of education includes pupils with mental

[1] Educode 2018: https://www.digitalwallonia.be/fr/publications/educode2018
[2] Ludovia 2019: https://ludovia.ch/2019/
[3] EIAH 2019: http://www.atief.fr/conference/ateliers-eiah-2019
[4] SETT 2019: https://www.sett-namur.be/
[5] https://school-it.info.unamur.be/

retardation and behavioral problems. *Differentiated education* is a type of secondary education used to manage and reduce disparities between pupils, manage class heterogeneity, and reduce grade repetition. It is intended for pupils who have not graduated from primary school.

When feasible, we collected data through two paper-based questionnaires following a pre-test-post-test design (Grieve, 1981; Dimitrov and Rumrill Jr, 2003). The use of paper questionnaires allowed us to provide additional information if one child could not understand some questions. Pre-test and post-test questionnaires allow measuring the impact of an activity on a group of individuals. This matches perfectly with our two research goals (i.e. RQ1a and RQ1b).

We asked the children to complete the pre-test questionnaire before the workshop and the post-test questionnaire after the workshop. Due to practical constraints, only ten to fifteen minutes could be allocated for each, which limited the number of questions we were able to include. All questions were open-ended in order to allow richer answers from children. The questions ask children to give their definition of a city, of a smart city, and the positive and negative points of a group discussion. Group discussions are central to the conduct of the workshop due to its focus on citizen participation, and actually central to many participation methods. Hence, the goal of the third question is to understand which elements are important for children in a group discussion. In the post-test questionnaire, the third question relates to the workshop specifically instead of group discussions in order to assess the workshop against the elements identified in the pre-test for future improvements. Another question is added on the post-test to ask children about the "smart city" project you would like to see in their city. The pre-test and post-test questionnaire can be consulted in Appendix B.

Although 299 children participated to the workshop sessions, the data collected through the questionnaires relates to a smaller sample. This was caused by several issues that occurred during the data collection process. First, due to time constraints, the questionnaire could not be completed by some children, as requiring them to do so would not have left enough time to complete the workshop. Nonetheless, valuable observations and feedback from the teachers could be collected. Second, several workshops were hosted with a substitute teacher who was in charge of the classes only for the time of the workshop. This caused various confusions that prevented data collection for an important part of the children. Third, non-attendance to class by some children resulted in them taking only the pre-test or the post-test. Overall, 52 (resp. 59) children completed only the pre-test (resp. post-test), and 130 complete questionnaire pairs were collected. For 16 of these 130 children, however, the questions specific to the post-test were not answered (there was a confusion in the paper questionnaires and those children completed the pre-test twice). Therefore, the findings presented in Section 6.4.2 relate on 130 children for the smart city definition and on 114 children for the other aspects. Overall, data could be collected for the differentiated and general education types, and across first, second, and third secondary. However, for first and third secondary, data was obtained for only one class. Table 6.1 gives detailed information for each session, namely the location, the workshop format, the school year, the education type participating children are enrolled in, the number of participants (#P), and the number of questionnaire pairs collected (#QPC) are indicated for each session.

Table 6.1: In-school sessions of the workshop that were organized. The location, the workshop format, the school year, the education type participating children are enrolled in, the number of participants (#P), and the number of questionnaire pairs collected (#QPC) are indicated for each session.

Location	Format	School year	Ed. type	#P (# females)	#QPC (# females)
Namur	2x100 minutes	2nd secondary	General	25 (11)	21 (9)
Namur	2x100 minutes	3rd secondary	General	16 (6)	15 (5)
Campus	1x90 minutes	3rd secondary	General	14 (7)	0 (0)
Campus	1x90 minutes	5th secondary	General	15 (11)	0 (0)
Campus	1x90 minutes	5th primary	Specialized	16 (7)	0 (0)
Campus	1x90 minutes	5th primary	Specialized	10 (4)	0 (0)
Namur	2x100 minutes	2nd secondary	Differentiated	16 (0)	10 (0)
Namur	2x100 minutes	2nd secondary	Differentiated	7 (0)	5 (0)
Ottignies	2x50 minutes	1st secondary	General	22 (9)	14 (1)
Ottignies	2x50 minutes	2nd secondary	General	25 (12)	19 (9)
Ottignies	2x50 minutes	2nd secondary	General	21 (6)	0 (0)
Ottignies	2x50 minutes	2nd secondary	General	23 (14)	19 (12)
Ottignies	2x50 minutes	1st secondary	General	21 (2)	0 (0)
Ottignies	2x50 minutes	2nd secondary	General	20 (10)	0 (0)
Ottignies	2x50 minutes	2nd secondary	General	24 (12)	7 (3)
Namur	1x150 minutes	2nd secondary	General	24 (13)	20 (11)
				299 (124)	**130 (50)**

6.2.3 Data Analysis

As all the questions asked in the questionnaire are open-ended, we performed manual coding of answers in order to draw conclusions on the collected data. Two researchers performed the coding independently and compared their respective results. The answers not coded alike by the two researchers were discussed with a third analyst to reach a consensus. Instead of defining a final list of codes beforehand, an exploratory coding methodology was used, where few codes were defined and refined throughout the coding process (Saldaña, 2015).

The first question of the pre/post-test was not analyzed. Its goal was to start the questionnaire with a question for which each child would have an answer to give, in order not to daunt answering from the beginning with a more complex question (Boynton and Greenhalgh, 2004).

The definition of the smart city given by the respondents was first analyzed with hypothesis coding (Weber, 1990), according to the two smart city orientations commonly found in literature and practice. Table 6.2 summarizes the codes and gives an example from the collected data for each. The *intelligent people*, *autonomous*, and *futuristic* codes are referred to as misconceptions, as they correspond to incorrect conceptions of the smart city. The seven codes are not exclusive. For instance, a definition stating that a smart city uses flying cars to ease citizen travel would fall under the technology, problem solving, citizen problem, and futuristic labels. In addition to the labels, the smart city dimensions mentioned in the definition were also noted, extracted according to the six dimensions described by Giffinger and Gudrun (2010). In the aforementioned example, the smart city dimension at hand would be labeled as "mobility".

Table 6.2: Codes assigned to the smart city definitions.

Code	**Description and example**
technology	The smart city contains ICT *Example: a city where there is a lot of technology*
problem solving	The smart city attempts to solve general problems *Example: a city where technology is mainly developed and which finds a solution to the problems*
citizen problem	The smart city attempts to solve general problems, and those problems are faced by citizens *Example: a city where leaders are trying to find ideas to make the city greener, more pleasant for citizens*
participation	The smart city involves citizens in decision-making *Example: it is a city in which everyone has the right to have their own opinion and to share it through technology, in particular*
intelligent people	The smart city has intelligent inhabitants *Example: a city with only intelligent people*
autonomous	The smart city is automatized, able to work without the citizens *Example: a city more focused on technology, a city that manages itself*
futuristic	The smart city has science fiction technologies (e.g. flying cars, serving robots) *Example: an organization of buildings controlled by intelligent and artificial robots*
no answer	No definition was provided

The question asking children about the smart city project they would like to see in their city was coded following the smart city dimensions and the codes used to analyze the smart city definition. As a project proposition corresponds to suggesting a solution to a problem, the problem-solving code was not used in the analysis of this question.

The question regarding the advantages and disadvantages of group discussions and of the workshop was analyzed by extracting all the individual elements mentioned and grouping the ones referring to the same idea together into categories following exploratory coding practices. Categories were defined and refined incrementally.

The answers to the question regarding the participation processes children would use to ask the public's opinion were analyzed by extracting any explicitly mentioned citizen participation process. For each process, four characteristics were noted. The *decision* indicates whether the participation process results in a decision (vote) or merely consists in polling the public (poll). The *digital* character indicates whether the proposed process involves ICT. The *method* refers to the concrete means used (e.g. application, website, door-to-door). Lastly, the *location* is the location where the participation process is implemented (e.g. city hall). It may occur that one or several of these four characteristics do not appear explicitly in the proposed process. In these instances, the process was described only with the elements that could be extracted. In cases where a respondent proposed several participation processes, all of them were noted and described separately.

6.3 Workshop Conduct

The workshop is divided into three parts: (1) a theoretical introduction of the smart city concept, (2) the realization of a city model with the children, and (3) the identification and resolution of urban issues on the model, with or without technology.

6.3.1 Theoretical Introduction to the Smart City (Step 1)

First, in the **theoretical introduction** step, a visual support with the theoretical content is presented to children (Figure 6.2). It shows the definition of the smart city on which the workshop is based, the six dimensions of the smart city (Note: the examples of smart city projects on the poster are not initially displayed on the poster), as well as the role of technology and citizens. Then, children are provided with examples of solutions and are asked to link them with the dimension(s) they think match best. Examples of solutions include providing online administrative services to citizens so that they do not wait long at the city hall. In this step, the workshop facilitator(s) should ensure that the children understand the examples correctly and provide additional explanations on each example when necessary. This step is referred to as Step 1.

6.3.2 Realization of a Model with the Children (Step 2)

Second, in the **realization of the city model** step (referred to as Step 2), we present the children with a city map in the form of a 2D paper plan with an empty map printed on it. The empty map is an abstracted geospatial map of an existing city. The buildings are not shown on the map, which displays only the roads, green areas, and watercourses. Then, we divide the class into four groups of even size and provide them with 15 buildings from the participatory role-playing game Democracity[6]. Democracity allows players to form political parties, to draw up programs, and to build a city. Then, we ask the children to debate and work as a local community council to select three buildings to place on the map. After building a first version of the city, we allow each group to suggest one modification to the city model such as adding a building, moving a building, etc. Figure 6.3 illustrates a city model constructed during the workshop design.

[6] https://www.belvue.be/en/node/192

Figure 6.2: Poster presented to children in the theoretical introduction. It shows the definition of the smart city on which the workshop is based, the six dimensions of the smart city, as well as the role of technology and citizens (Note: at the beginning of the workshop, the examples of smart city projects are not initially on the poster, children are asked to assign them to the correct dimension(s)).

6.3.3 Identification and Resolution of Issues (Step 3)

Third, in the **identification and resolution of issues** step (referred to as Step 3), we give children the opportunity to reflect on the potential urban issues that could happen in the current city model. These issues can be represented on the city model directly (e.g. toy cars aligned to represent congestion, checkers piled to represent garbage overflowing from bins). After selecting one issue to tackle (i.e. after reaching consensus through discussion or voting), we ask the children to think about potential solutions to solve this issue. Children can take inspiration from

Figure 6.3: City model constructed during the workshop design.

the smart city solution examples of Step 1. The solution chosen by children is then implemented thanks to programmable devices suitable for novice programmers such as Makeblock Orion[7] or micro:bit[8]. The Makeblock Orion is a control board on which various sensors (temperature, movement, etc.) can be plugged to build a solution, and the micro:bit is a pocket-size computer equipped with sensors, physical buttons, and a screen with 25 LED lights for display. We relied on such tools because previous works noted that technologies can increase children's interest in areas that are less attractive to them (Hennig, 2019).

6.3.4 Duration

The workshop is intended to be organized over two separate sessions of two class hours (i.e. a class hour is equivalent to 50 minutes) each, the first being dedicated to Step 1 and Step 2 and the second to Step 3. However, the teaching hours available for the workshop did not always match the conduct as initially devised. This resulted in four different formats being designed. Some involve giving the workshop in two parts separated by one to two weeks of time. The formats are detailed in Table 6.3.

[7] https://www.makeblock.com/project/makeblock-orion
[8] https://microbit.org/

Table 6.3: Conduct description of the four existing formats of the workshop.

Teaching hours	Conduct
2 sessions of 100 minutes	The first 100-minute session is dedicated to the first two steps of the workshop. The second session is dedicated to the third step. The steps are conducted as described in this section.
2 sessions of 50 minutes	The first 50-minute session is dedicated to the first two steps of the workshop. However, the facilitators present themselves one example per dimension in the first step, and the poster is displayed in full as in Figure 6.2. In the realization of the model part, the model modification round is skipped. The second session is dedicated to the third step. Less time is given to the children to complete the exercise and less time is dedicated to the discussion after the presentation of the solution.
1 session of 150 minutes	The city model was built beforehand by the children in the context of another class activity. Thus, the realization of the model step was skipped and the identification of issues could be started straight after the theoretical introduction. This allowed conducting the first and third steps as described in this section.
1 session of 90 minutes	Due to timing constraints, the theoretical introduction was accelerated by discussing less examples with the children. The discussion on participation methods was also skipped in order to have enough time to build the city model. Rather than a hands-on exercise, the third step was replaced by a brief introduction to the micro:bit programming interface and a demo on how to build a voting system with it.

6.4 Workshop Evaluation

The evaluation of the workshop was conducted in two steps. First, a preliminary evaluation with one class served as trial run to make the necessary adjustments to the workshop conduct. It is presented in Section 6.4.1. Second, a large-scale evaluation was carried with 14 additional classes, involving the four workshop formats and the three Belgian education types (Table 6.1).

The results reported for the preliminary evaluation concerns only the first class listed in Table 6.1. It is composed of 25 children (21 having attended the workshop and from whom data could be collected) enrolled in the second year of general secondary education. Since the data collection questionnaire was not modified, the data collected in the preliminary evaluation is included in the results reported for the large-scale evaluation.

6.4.1 Preliminary Evaluation

The first in-school session of the workshop served as a trial run. Its goal was to determine whether the workshop conduct as planned is actually feasible given the constraints of the school context, especially the time available. We also wanted to have an idea of the level of engagement of children throughout the workshop and to compare a first round of pre-test and post-test questionnaire to determine if changes in the conduct were necessary before the large-scale evaluation.

The class which participated in the preliminary evaluation is the first reported in Table 6.1. It is composed of 25 children (21 having attended the workshop and from whom data could be collected) enrolled in the second year of general secondary education. In the following paragraphs, we describe how the workshop took place with these children, following the 2x100 minutes format. The workshop was organized over four hours split into two-hour sessions. The first session was dedicated to the first and second steps of the workshop. During the next session, which took place seven days later, the third step was conducted.

During the first step of the workshop (approximately 30 minutes), we observed that children were able to link the provided examples with the smart city dimensions fairly accurately. The economy and governance dimensions were however under-represented in children's propositions. One explanation is that these dimensions concern aspects that children encounter less in their everyday life. On the contrary, the living and environment dimensions were over-represented. One explanation is that the living dimension is inherently broader that the others. As for the environment dimension, it is also recurrent in the smart city definitions in the pre-tests. We believe that the prominence of environmental concerns is due to the numerous news on climate mobilization at the time of the workshop.

In the second step (approximately 1 hour 30) , the children successively placed three buildings per group and then one building per group. In the model revision round, every group chose to add a building to the model. Figure 6.4 shows the buildings chosen by the children and their location. We observed that although some buildings were placed somehow arbitrarily, others were placed anticipating potential issues. An example is the placement of the public transport facility nearby the train station by group 2. They placed it there to ease the access to public transports for people arriving in the city from the train station, and said they wanted to allow workers to reach the multinational corporation placed by group 1 in the periphery easily. Another example is the placement of the police station at the middle of the model to allow fast interventions anywhere. After the city model was completed, discussions emerged about the misplacement of the mall, as it would cause congestion if placed in the city center. All children agreed to move it elsewhere, but were divided regarding its new location. Children were thus asked to list decision processes to solve such an issue and to vote for their preferred one. Table 6.4 lists the six decision-making processes thus obtained and the number of votes each received. We were surprised by the maturity of the children's reflection at this point. They considered issues such as ensuring the representativeness of voters. They suggested public displays as a way to consult senior citizens who cannot use a computer or do not own one. The decision process that received the most votes is the online voting. Therefore, we decided to implement a voting system using micro:bit in the last step of the workshop. A one-week break between the second and third step allowed us to focus on the voting system development and to make the necessary preparations beforehand.

In the third step of the workshop (approximately 2 hours), children worked in groups of two with the micro:bit to implement a voting system that allows consulting citizens on a possible relocation of the mall. The system takes the form of a single

Figure 6.4: City model completed by children during the preliminary evaluation. The buildings placed are numbered from 1 to 16. Buildings 1 to 12 correspond to the 3 buildings initially placed for each group. Buildings 13 to 16 are those placed in the model modification round. The buildings are as follows: (1) train station, (2) public transport, (3) mall, (4) pharmacy, (5) high school, (6) park, (7) parliament, (8) cultural centre, (9) police station, (10) primary school, (11) sports hall, (12) multinational corporation, (13) fire station, (14) cafe, (15) university, and (16) hospital. The purple dot at the center of the map corresponds to the location of the school where the workshop was conducted.

Table 6.4: Decision-making processes listed by the children

Decision process	**Votes**
Elected officials voting	0
Citizens voting	0
Shared decision (officials and citizens)	10
Only children voting	2
Petition	1
Internet voting (website and public display)	11
Blank vote	1
Total	25

micro:bit that can be interacted with through its buttons to cast a vote *in favor* of relocating the mall, *against*, or *blank*. The micro:bit would then display a smiley as visual feedback that the vote was cast, and send the vote through the radio feature implemented in the micro:bit to a centralized vote counter. Figure 6.5 (right) shows a representation of the micro:bit running the voting system. Figure 6.5 (left) shows the block code handling the *in favor* vote. The code is composed of one main block capturing the button press, as well as two nested blocks handling the visual feedback display and the sending of the vote to the centralized counter respectively. Due to the limited time available and to the fact that most children knew neither programming concepts nor the micro:bit, the centralized vote counter was developed beforehand and brought to the workshop. It is represented in Figure 6.6 and consists of a cardboard box holding one micro:bit per voting option. Once every children had successfully implemented the voting system, they discussed the real-life limitations of such a voting system deployed in a city. Issues such as vote privacy and the possibility of voting multiple times were raised.

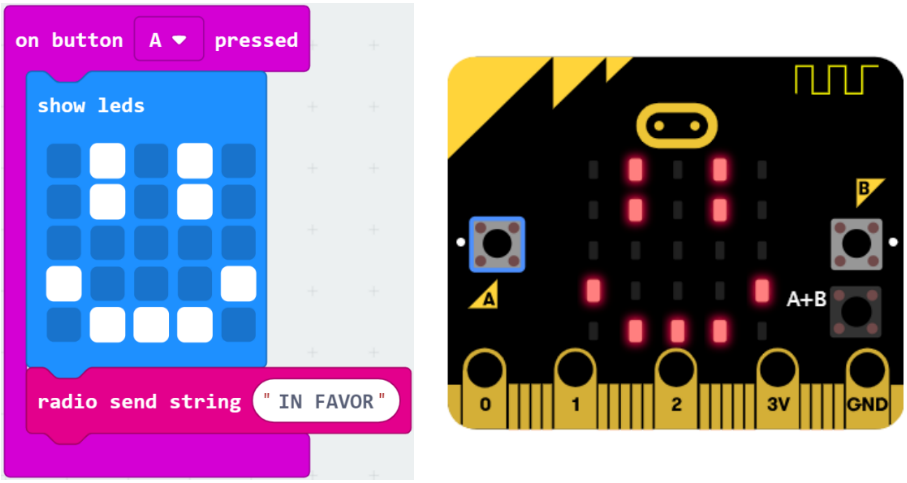


Figure 6.5: Code (left) and execution (right) of the voting box developed by the children using the micro:bit.

Thanks to the insights gathered from the pre-tests and the post-tests filled by 21 children, we were able to analyze the evolution of their understanding of the smart city concept. The most striking evolution resides in the "problem solving" approach that children adopted. Indeed, in the pre-tests, only three children noted that the smart city must solve citizens' daily issues. At this point, the predominant definition of a smart city was a city that contains technology, but without specifying any purpose for technology use in the definition. In the post-tests, this number increased to ten children mentioning that the smart city must "answer the questions of citizens", "use technology appropriately" or "improve the quality of life of citizens".

These encouraging results led us to keep the workshop conduct as-is for the large-scale evaluation. Due to the enthusiasm of the children we observed during

Figure 6.6: Vote counter displaying the aggregated results from the voting boxes developed by the children.

the discussion on participation methods, we decided to keep the development of a voting system as programming activity in the third step. Indeed, as explained in Section 6.3, one goal of this step is to increase children's interest. Furthermore, keeping the same activity in the third step allowed having comparable results over the workshop sessions.

6.4.2 Large-Scale Evaluation

The Workshop as an Educational Tool (RQ1a)

Smart City Definition Figure 6.7 shows the number of definitions that were assigned the different codes, as well as the number of children who did not provide an answer to the question, either by writing that they do not know or by not writing anything. 35 of the 130 definitions were an answer that did not match any code. In most cases, they corresponded to children defining a smart city as an environment-friendly city, thus relating to the environment dimension but to no code. The *technology* code is still strongly present after the workshop. However, a substantial increase can be observed for the *problem-solving*, *citizen problem*, and *participation* codes. As for the misconceptions, they decreased overall. The number of children who did not answer the question or whose answer did not match any code decreased by approximately half. No significant difference between males and females was found.

Although comparing the assignation numbers for each code before and after the workshop provides very interesting insights, it is essential to analyze the transition between these different visions. In order to achieve this, a fingerprint was associated with each smart city definition from the tags assigned. In total, five distinct fingerprints were defined from the initial codes (see Table 6.5).

Figure 6.8 shows a Sankey diagram representing how children shifted from one fingerprint to another in the smart city definition they gave in the pre-test and the

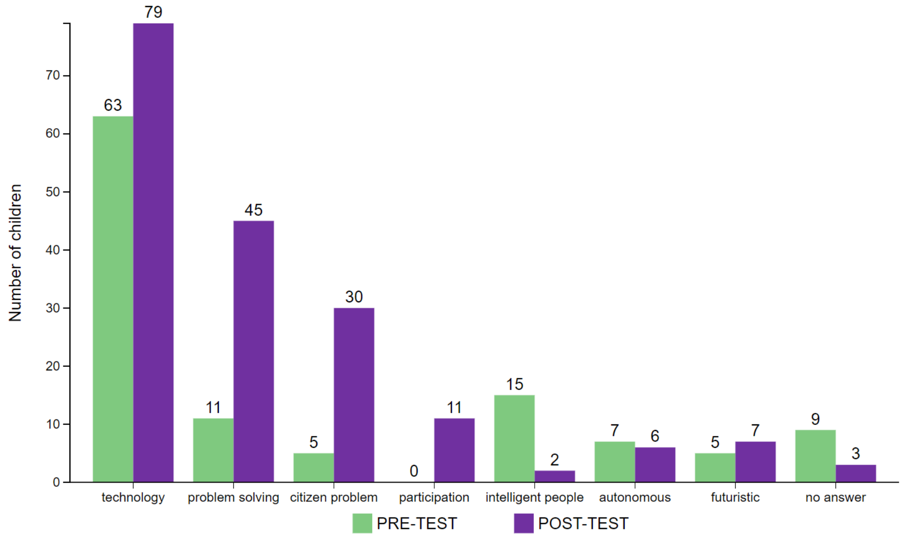


Figure 6.7: Number of smart city definitions being assigned the different codes, for the pre-test and the post-test questionnaire.

Table 6.5: Fingerprints associated with the smart city definitions.

Fingerprint	**Description**
technology	Only the technology code was assigned
good	Either the problem-solving, the citizen problem, or the participation code was assigned, regardless of any other present code
no code	The question was answered, but no code was assigned
misconception	None of the problem-solving, the citizen problem, nor the participation code was assigned AND either the intelligent people, autonomous, or futuristic code was assigned
no answer	The question was not answered

post-test. The most frequently assigned fingerprint changed from *technology* to *good*. In fact, the frequency of all fingerprints except for *good* decreased after the post-test, many children having transitioned to this fingerprint.

Figure 6.9 shows the number of times the smart city dimensions are mentioned in the definitions, for the pre-test and the post-test questionnaire. *Environment* is the smart city dimension mentioned the most in the definitions. In many instances, a smart city is defined as a city that respects the environment, an ecological city (e.g. "an ecological city, with less pollution and more greenery"). Another recurrent dimension is *mobility*. This dimension often appears with the technology orientation, as children frequently exemplify the use of technology with transportation means. It

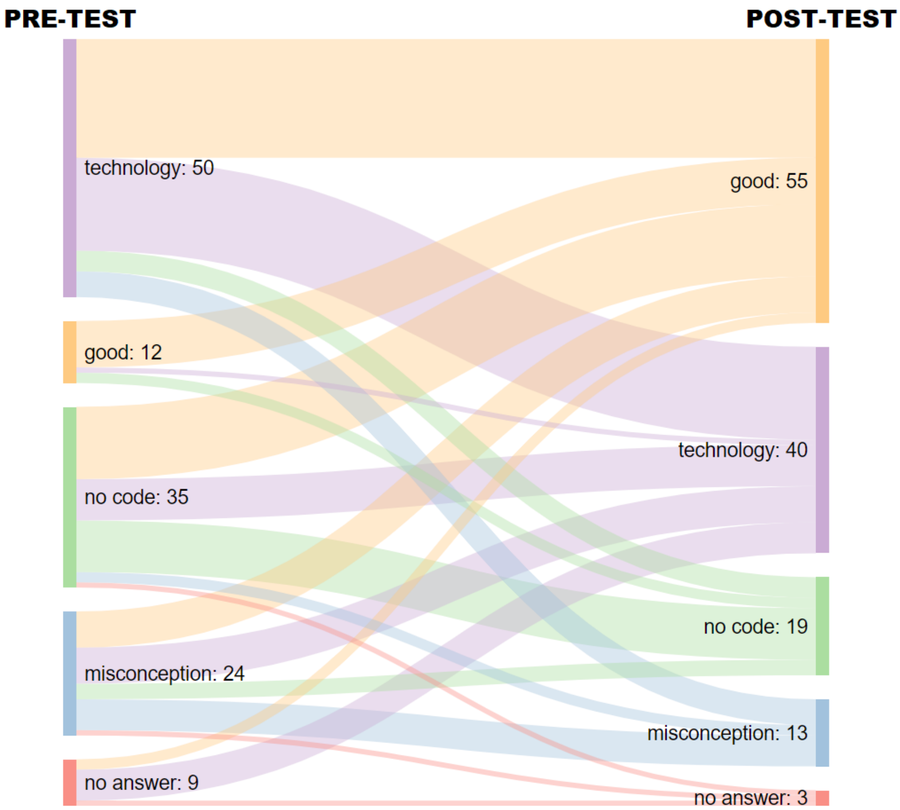


Figure 6.8: Sankey diagram representing how children shifted from one fingerprint to another in the smart city definition they gave in the pre-test and post-test questionnaire.

also appears along with the environment dimension. Some children pushed their thinking further when they defined a smart city as environment-friendly by providing concrete solutions (e.g. “a city with fewer cars and more bicycles”). Conversely, the *economy*, *people*, *governance*, and *living* dimensions are mentioned marginally. They cover aspects of the urban life that are of lesser concern to children, such as employment, citizens’ level of qualification, and public services. However, due to its larger scope, more occurrences of the living dimension were expected. Instead of mentioning areas such as health and tourism, 4 of the 5 definitions from the pre-test falling into the living dimension discussed examples of using technology to improve security (e.g. “a city where there are surveillance cameras”). The majority of the proposed definitions do not explicitly mention any of the six smart city dimensions. For the main part, they correspond to definitions where misconceptions of the smart city appear (e.g. “a city where there are only intelligent people”), where the smart city is solely defined by the presence of technology, or to the absence of answer for the question.

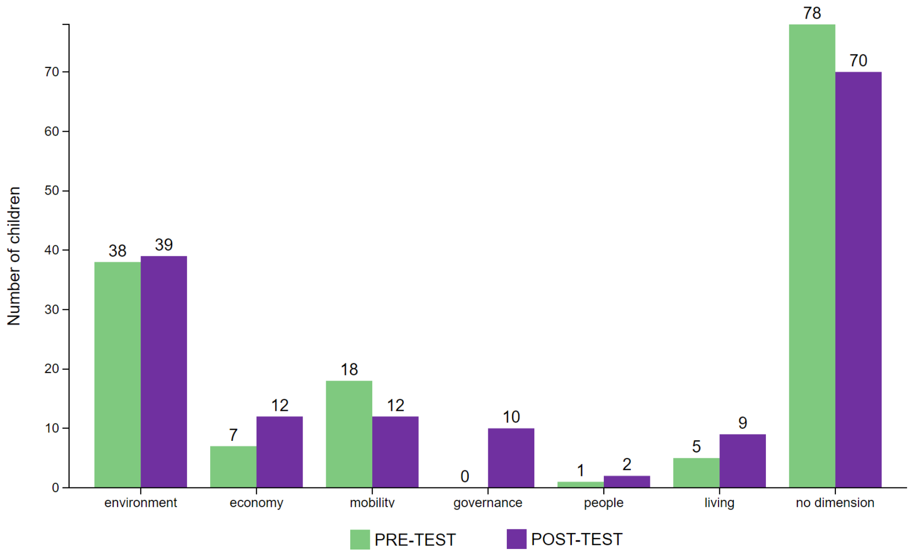


Figure 6.9: Number of times the smart city dimensions are mentioned in the definitions, for the pre-test and the post-test questionnaire.

In the post-test, the economy, living, and governance dimensions have more occurrences and the mobility dimension is less frequent. The increase is especially striking for the governance dimension, which appeared in 10 definitions while being totally absent from the pre-test. Unlike the pre-tests, some children also define the smart city as a city that works to solve problems, without explicitly mentioning the dimension into which these problems fall (e.g. "a city that innovates and finds solutions to the problems of its citizens").

Smart City Project Concerning the orientations of the suggested ideas, half the projects involve *technology* (see Figure 6.10). The other two present orientations are the *participation* and the *futuristic* ones. 18 children did not provide any answer to the question, or stated that they do not know what smart city project to propose. A type of response we discriminated from this are answers stating that no smart city project is wanted, as the city is already fine as-is. Four children answered the question as such. 39 children proposed a smart city project not matching any orientation. These are for the most part projects consisting in adopting more sustainable behaviors such as having garden projects or free public transports.

The smart city dimensions mentioned in the proposed projects were extracted as well. Overall, two dimensions stand out, namely *environment* and *mobility* (see Figure 6.11). We observed that environment and mobility appear together in many project propositions, as the most frequent solution suggested to tackle environment issues is to promote public transport and bikes at the expense of cars. As for the *governance*, *living*, *people*, and *economy* dimensions, they appear less frequently, either by reusing the examples presented during the first step of the workshop (e.g.

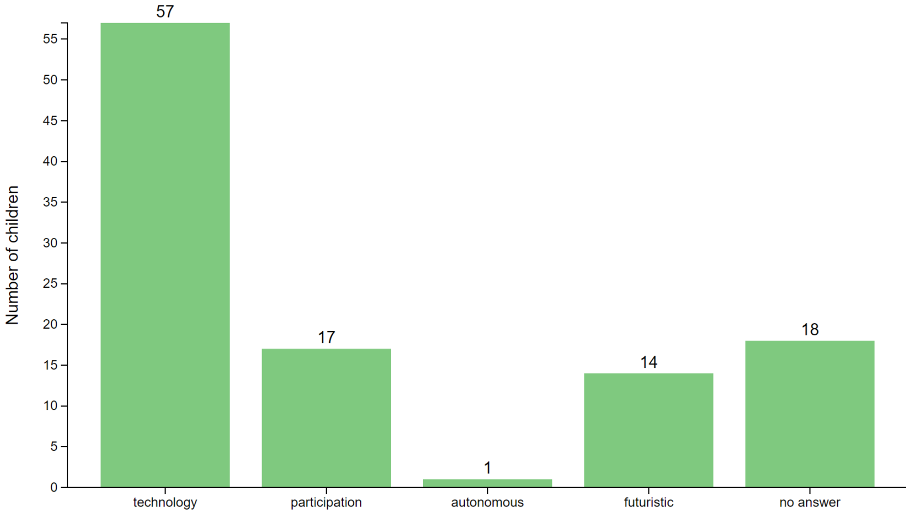


Figure 6.10: Number of smart city projects being assigned the different codes.

smart bins and smart lightning) or by proposing to implement voting systems. In some instances the children's personal context made mobility projects emerge, such as adding a specific bus line to better accommodate their own transportation needs. Finally, there are many project propositions in which no dimension is explicitly mentioned. They mainly include absence of answer, answers stating that no project is wanted, and projects that solely propose to add technology to the city (e.g. "more technology in the city").

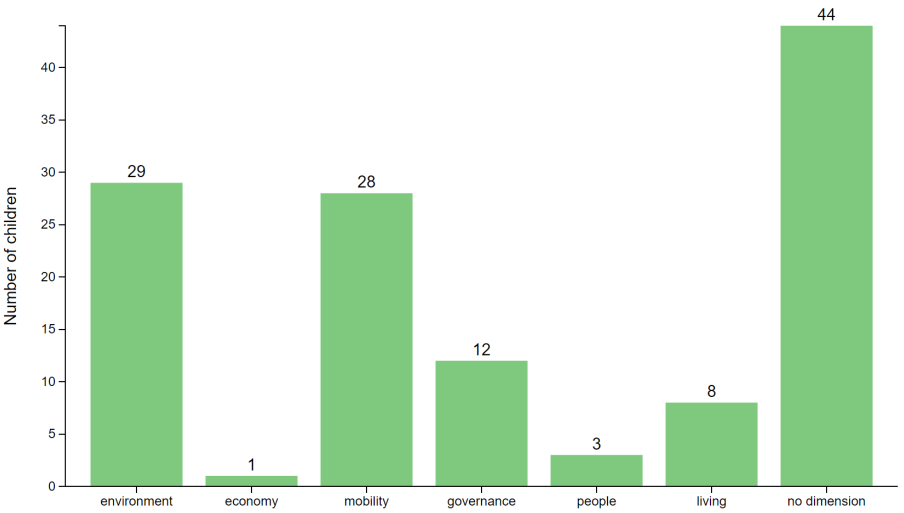


Figure 6.11: Number of times the smart city dimensions are mentioned in the projects.

Participation Methods 21 children did not propose any participation process, 79 proposed one process, 13 children noted two processes, and 1 child listed three. In total, 108 participation processes were described. Figure 6.12 shows a tree diagram regrouping all the participation processes proposed by the children. The second, third, and fourth level nodes of the tree are related respectively to the *decision*, *digital*, and *method* characteristics. A path in the tree defines a participation process characterized by each node it crosses. The number of times a participation method was proposed is noted between parentheses along each leaf node. The greater order frequencies are noted along the internal nodes of the tree.

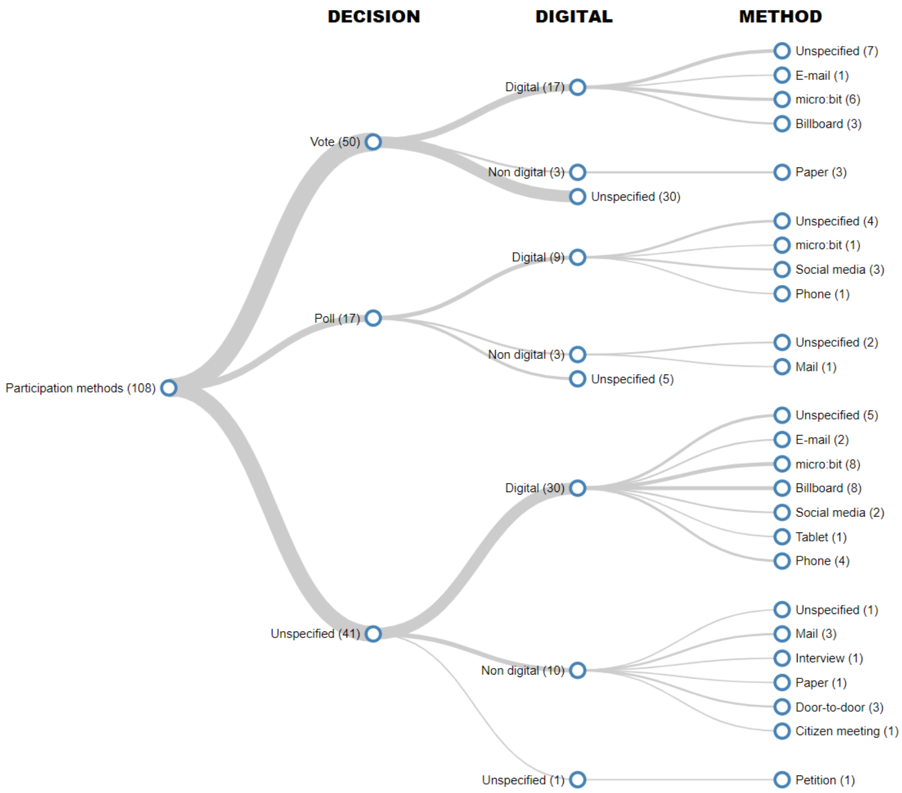


Figure 6.12: Participation processes proposed by the children. The second, third, and fourth level nodes of the tree are related respectively to the decision, digital, and method characteristics. A path in the tree defines a participation process characterized by each node it crosses.

Children's Opinion on the Workshop (RQ1b)

The positive and negative points raised by the children are listed in Table 6.6 for group discussions and in Table 6.7 the workshop. Regarding group discussions, 21 (resp. 31) children did not mention any positive (resp. negative) point. Concerning the workshop, 36 (resp. 61) children did not mention any positive (resp. negative) point. Substantially less children mentioned negative points for the workshop than for group discussion, which is an encouraging result.

Table 6.6: Positive and negative points of **group discussions**. The number of times an aspect was raised by the children is noted in parenthesis.

Positive points	**Negative points**
Opportunity to give one's opinion (50)	Disagreements (30)
Opportunity to hear others' opinion (43)	Conflicts (29)
More ideas can emerge (11)	Interruptions (11)
Opportunity to change one's or others' opinion (9)	Noise (7)
Opportunity to learn new things (7)	Having to wait one's turn to speak (6)

Table 6.7: Positive and negative points of the **workshop**. The number of times an aspect was raised by the children is noted in parenthesis.

Positive points	**Negative points**
Opportunity to give one's opinion (22)	Disagreements (15)
Opportunity to learn new things (15)	Non-participation of some classmates (6)
Opportunity to hear others' opinion (11)	Stubbornness (5)
It was fun (7)	Influence of others on one's opinion (5)

The main positive and negative points are fairly similar for both group discussions and the workshop. Nonetheless, some discrepancies are to note. First, the opportunity to learn new things was raised twice more frequently for the workshop. Second, the fun character of the workshop was raised in several answers. Third, the opportunity to change one's or others' opinion and the fact that more ideas are able to emerge were mentioned respectively 2 and 3 times for the workshop, thus less frequently than for group discussions.

6.5 Lessons Learned

We would qualify the 2x100min format as ideal for a proper implementation of the workshop. Indeed, leaving one full session for the programming activity enables to answer in-depth the questions of the children and to discuss the challenges and limitations of smart city solutions. Furthermore, the best evolution in the children's understanding of the smart city concept comes from the classes where this format was used.

The 2x50 format also enabled to dedicate one session to the programming activity. However, getting the children's interest and concentration in 50 minutes was challenging. Furthermore, the discussions were not going as deep as with the 2x100min format. We would therefore not recommend to use this format. The workshop is also less marking, some children having completed the post-test several weeks after workshop noted that they did not remember the workshop at all.

The 1x150min session was considered too long by the children in terms of concentration efforts. Furthermore, the city model was constructed beforehand by the children for another class. This was detrimental to the quality of the workshop as the city was less realistic than in the other workshops and we were not able to discuss concrete urban issues as easily on that basis. Consequently, the children did not seem as engaged in the programming activity. Starting with the theoretical introduction and debating concrete urban issues is what really enables children to understand the purpose of the smart city solution.

Regarding the 1x90min format, we did not capture information about the children's understanding through questionnaires but we noted that the timing was too short to go in-depth into each step of the workshop. However, several children still showed interest and willingness to program after the presentation of the smart city solutions with micro:bit. Indeed, as expected, the programming activity played an important role in making the workshop more enjoyable. Several children who could participate in the programming activity with the other workshop formats explicitly mentioned it as a positive point of the workshop in the post-test questionnaire, and we thus believe it contributed to the playful character of the workshop. However, the programming activity alone is not sufficient. Due to data collection issues, 21 children participated only to the third step of the workshop and therefore completed only the post-test. In their definition of the smart city, 13 of the 21 children mentioned the technological orientation of the smart city. Strikingly, none mentioned anything related to problem-solving, citizen problems, and citizen participation, despite the programming activity consisting in developing a voting system. Regarding participation methods, only 4 children proposed one.

On a more general note, two aspects we believe would be essential to work toward are the opportunity to change one's or others' opinion and the fact that more ideas are able to emerge. Indeed, they are important positive points of group discussions but they were mentioned on rare occasions for the workshop. One possible explanation is the fact that children were divided into small groups for activity involving a group discussion, namely the building of the city model. The model was then constructed by building up the results of these smaller scale group discussions, with children not immediately given the opportunity to question the choices of other groups than their own during the model construction. Some answers may concern the part when the decisions of the groups are shared to build the model, rather than the discussion that led to these decisions, inside each group. Therefore, it is essential to take the necessary time to allow children to debate ideas at all steps of the workshop.

Drawing from these observations, we would recommend practitioners:

- To hold the programming activity in a separate session.
- To dedicate enough time (75 minutes would be a minimum) for each of the two sessions to allow children to discuss the concepts and debate ideas.
- To challenge the children as much as possible at each step of the workshop. For the theoretical introduction, we asked them about the limitations of the examples of the solutions. For the model construction, we discussed the real-life political process with them. Finally, for the programming part, we challenged their solutions in terms of feasibility, privacy, representativeness, etc.
- To keep the playful character and stimulate it as much as possible during

each step of the workshop. Even though it was given to children of different ages, we observed that having a playful experience really helps to capture their attention and increases their willingness to learn. The programming activity was useful to stimulate the playful character of the workshop.

6.6 Tabletop Tangible Interaction

The workshop proposal and its first results were presented at several conferences and exhibitions and have sparked a strong interest among the attendees. Precious feedback was received from public servants, researchers in citizen participation, digital education experts, and teachers.

One limitation of the workshop that was observed throughout the sessions is the lack of depth of the debates around the city model, which is limited by its low interactivity. Indeed, when placing a building on the model, no information on the impact of the building on its vicinity (e.g. noise, road congestion) is rendered, which makes it difficult for children to ground their discussions. Instead, the debates were driven by children's personal preferences or by high-level questions such as the overall concentration of buildings. In this section, we describe the work conducted to solve this issue. The resulting contribution was developed with two students in the context of master thesis in computer science supervised by the author of this thesis and his advisor.

The search for a solution to this issue started by an analysis of several city construction games that incorporate smart city related issues such as environment. As detailed in Section 6.2.1, the rigor cycle involved analyzing the literature. Therefore, in order to search in a complementary way, we stepped back from the literature and we made a selection of games (including both board and video games) using non-academic search engines. From our analysis of five games and of the original workshop, one trend emerged. Board games are successful in sparking debate and fostering interaction between participants. However, they involve paper and plastic items which fail at giving a dynamic and visual response to participants' actions. On the contrary, the strength of video games is that the impact of participants' actions can be displayed visually and in real-time, but collaboration and discussions are impeded by the use of individual machines.

The best of both worlds could thus lie in collaborative technologies. One such technology is tangible interaction, which has been reported in the literature as especially suited for collaborative work and discussions (Schneider et al., 2010; Horn et al., 2012), and implemented in the classroom environment (Higgins et al., 2011). Previous studies have demonstrated the high potential of such systems in supporting learning activities for children (Almukadi and Stephane, 2015; Kubicki et al., 2015), including in a classroom setting (Kubicki et al., 2015). Dillenbourg and Evans (2011) discuss the advantages of tabletops in supporting educational activities. Among others, they report that tabletops are designed to support multiple users, for co-location, and for hands-on activities, which are essential aspects of the workshop that our proposal should preserve. Furthermore, tangible interaction has been successfully applied to urban planning activities (Underkoffler and Ishii, 1999), which are related to the city model building part of the workshop.

We envisioned the improved city model as an interactive table onto which an empty city map would be projected. The buildings placed on the table would then be recognized by a unique identified and data on the impact of the building on e.g. road congestion or pollution could be projected onto the city map to fuel the discussions.

We chose to develop the table using the reacTIVision framework (Kaltenbrunner and Bencina, 2007) to reuse existing infrastructure. The tables using this framework are all based on a similar architecture. A camera placed below or above the table captures the movements of specific fiducial markers. A computer containing the client application captures these movements and interprets them. Via a projector, a visual representation is finally produced and displayed on the table screen. reacTIVision is an open source framework that defines a common API for interactive surfaces. The abstraction it offers allows the rapid development of functional interfaces for this type of medium.

The table has to be usable by 12-14-year-old children and the workshop has to fit within two class hours due to field constraints. Therefore, interaction needs be kept as simple as possible and children should be able to use the table without time-consuming training beforehand. For these reasons we designed only two types of fiducial markers, namely the buildings and the domain views. The buildings were not changed from the original workshop. They were originally selected to ensure sufficient diversity, and no issue concerning the selection were reported by the children during the evaluations. The domain views are related to one specific domain such as mobility or environment and, when placed on the table, act as filters showing the impact of all present buildings on the domain they represent. Domain views have a circular shape allowing them to be quickly differentiated from the buildings.

The challenge was to ensure a complete coverage of the smart city dimensions (Giffinger and Gudrun, 2010) while not inducing too much complexity in the workshop. Therefore, eight domains were selected. **Mobility** describes the impact of buildings on road congestion, in terms of how many citizens they attract. **Health** describes the sanitary impact in terms of services provided. **Well-being** concerns the satisfaction of different age groups. **Noise** regards the noise disturbance caused by the buildings. **Economy** indicates the proportion of funding (i.e. public and private money) for the buildings. **Safety** concerns the impact on security. **Environment** reflects the pollution caused by the buildings. Finally, **Energy** quantifies the energy consumed and produced by the buildings. When placed on the table, domain view markers display the impact of every individual building through visual effects around the building marker. The information of all buildings are also aggregated to give a global view on the city that is projected around the domain marker. To avoid the visual clutter that would result from overlapping representations, we decided to allow only one domain to be considered at a time. Figure 6.13 shows the prototyped domain view markers.

Figures 6.14a–6.14h illustrate how the impacts are visually projected onto the city

Figure 6.13: Prototype of the domain view markers (English translation from left to right: mobility, health, well-being, noise, economy, safety, environment, energy)

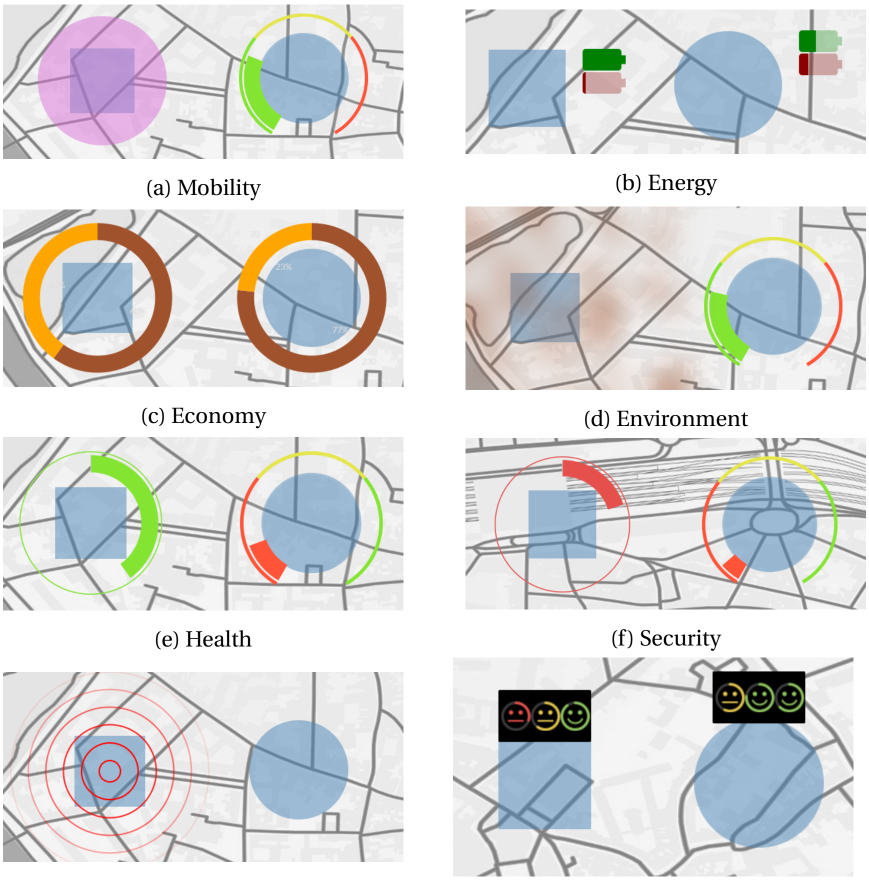
map. The impact representations were designed in order to convey the information in the simplest way possible, considering that the target end-users are children. When feasible, consistency was kept between the representations of the individual buildings impact and the citywide impact. Concerning mobility (Figure 6.14a), congestion is depicted by a purple circle around each building. A wider circle represents a more severe congestion, symbolizing the fact that more severe congestion generally impacts mobility in a larger geographical area. Overlapping circles also help identifying highly impacted areas. The citywide congestion is represented by a three-color gauge ranging from green (i.e. overall fluid traffic) to red (i.e. overall highly congested traffic). Regarding energy (Figure 6.14b), consumption and production are represented respectively by a green and a red battery. The battery metaphor is among the best-known for representing energy data, and is frequently encountered by children, notably on devices to denote the power level. The filling of the batteries indicates a higher production or a higher consumption. The citywide energy situation is represented in the same way. As for economy (Figure 6.14c), a donut chart around each building gives the funding proportion for public (yellow) and private (brown) spending. The citywide situation is represented in the same way. The impact on pollution (Figure 6.14d) of each building is represented by a rust-colored cloud surrounding it, with larger clouds indicating a more polluting building. The overall impact is represented by a three-level gauge. Regarding health (Figure 6.14e), the contribution of each building to the provision of health services is represented by a circular green gauge. A further filled gauge represents a higher impact. The citywide situation is again represented by a three-level gauge which however starts with the red color. A less filled gauge represents a lower amount of health services, and therefore a negative situation, which is why the health gauge goes from red to green. The same representations were chosen for security (Figure 6.14f), with a change in color for the impact of the buildings to avoid confusion with the health domain view. A less filled gauge represents a lesser contribution to citizens' safety. Concerning noise (Figure 6.14g), the impact was represented by red circular waves emanating from each building, following the sound propagation metaphor. Waves with a larger radius indicate that more noise is generated. Overlapping waves indicate areas subjected to high noise disturbance. The overall impact was not represented visually. Contrary to the other domains, the impact of noise remains strictly local to the disturbed areas. Instead, the domain view represents the noise level of the specific location on which it is placed. In order to provide a more realistic insight into the nuisance, the noise was represented by playing a city noise audio file at the corresponding volume. The drawback of this approach is that the table has to be equipped with speakers. Lastly, the impact on well-being (Figure 6.14h) was represented by three colored smileys, each depicting the satisfaction level of an age group. The considered groups are children (i.e. under 18 years old), adults (i.e. 18 to 65 years old), and elders (more than 65 years old). Three levels of satisfaction are represented by a neutral red smiley, a neutral yellow smiley, and a happy green smiley. The filling level of the outer border of the image gives a finer-grained information. We chose to sideline unhappy smileys to avoid confusion between satisfaction and happiness. A citizen can find no interest, and therefore no satisfaction, in a building, without having her happiness level affected because of it. The information of all buildings is aggregated to represent overall satisfaction levels using the same representation.

In the original workshop, children are divided into four groups, each deciding on three buildings to place on the city map. We therefore generated completed city model examples and examined how the impacts are projected onto the city model to ensure that there is no information overload. Figure 6.15 shows an example of a city model holding 12 buildings and the environment domain view. The individual and collective impacts of the buildings as projected onto the city model are presented in Figure 6.16. The projected impacts remain easy to read with 12 buildings. However, projecting the impact for more than one domain would certainly cause a too high visual clutter.

While introducing tangible interaction to the workshop is a promising avenue, it would be detrimental to two convenient aspects of the original workshop that should be acknowledged. First, one advantage of the original workshop is that it is possible to transport the necessary equipment to any place, which allowed us to move from class to class. Naturally, an interactive table is tedious to carry around. Second, another advantage is the cost of the equipment. In total, the buildings and the city model are an expense under $100 and do not require any specific skill to set up. However, the construction of an interactive table as described requires much more resources, time, and technical skills.

6.7 Limitations

In this section, we present four limitations of the research reported in this chapter. The first three concern the large-scale evaluation, and the last one the tangible interaction table.



(a) Mobility (b) Energy (c) Economy (d) Environment (e) Health (f) Security (g) Noise (h) Well-being

Figure 6.14: Representation of the impact of individual buildings (left) and on the city as a whole (right), for each domain

6.7.1 Long-Term Impact of the Workshop

The post-tests were completed by the children a few days or weeks after the workshop. In one school, there was an issue that led to 59 children completing the post-test several weeks after the workshop, later than we planned. Overall, we observed a lower quality for this data. All these children participated in the 2x50 minutes workshop. It would thus be interesting to determine whether this issue is specific to this format. More generally, it would also have been interesting to assess whether the impact of the workshop persists by administering a third follow-up questionnaire several months after the workshop. This would however have been tedious to achieve. We only captured the necessary information to match the pre-test and the post-test questionnaires, and the workshop were given during the second semester of the school year. Therefore, several months after the workshops, the children would have started a new school year and been in a different class, and it

Figure 6.15: Example of city model that could be built during the workshop. The environment domain view is placed on the city map.

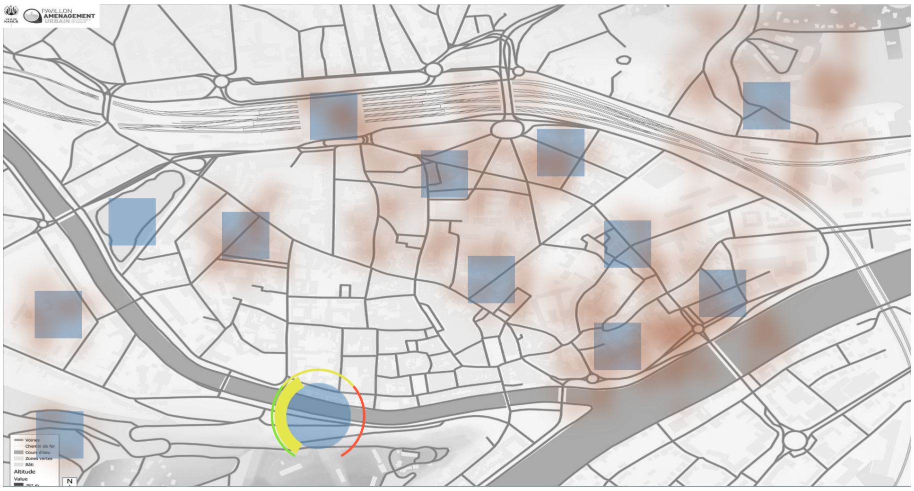


Figure 6.16: Projected impact of the buildings on the environment

would have been impossible to trace them back for a follow-up questionnaire.

6.7.2 Learning Levels Supported by the Workshop

Two levels of learning in decision-making are distinguished by Argyris (1976). Single-loop learning refers to "learning about the rules," that is, learning from the outcome of an action. Double-loop learning goes one level deeper and questions not only the actions but the assumptions. It is sometimes referred to as "changing the rules." These levels of learning in decision-making are also relevant in the context of citizen participation, since it is defined in this thesis as the involvement of citizens into decision-making processes. The workshop supports single-loop learning by imposing a participation method, namely the group discussion, to children while building the city model, and having them reflect on the outcome of this action. Interestingly, the goal of this step was primarily to have them take on the role of representatives taking decisions. However, as explained in Section 6.6, the discussions were driven by personal preferences, and children discussed in a large extend as citizens in their own name rather than elected representatives. Second-loop learning takes place when children go one level deeper and question the limitations of participation methods, and therefore question the rules of participation and discuss how to change them to make participation more accessible to the population.

Another level of learning, referred to as third-loop learning, has been defined later and consists in reflecting how learning is done. It is sometimes called "learning about learning." Although the origins of this level are unclear, it was inspired by the two levels defined by Argyris (1976) for decision-making (Tosey et al., 2012). Hurlbert and Gupta (2015) argue that third-loop learning is necessary for citizen participation in the context of complex unstructured problems. However, this level is not currently supported by the workshop. While this can be viewed as a limitation, we instead argue that it should not be the role of the workshop to support this level of learning. Instead, participation activities should be organized for children in order to give them the opportunity to put what they learnt in the workshop into practice, and cultivate this through continuous learning of participation in doing so, and even teach it to new young participants. This reiterates the call from the UNICEF and several researchers (Riggio, 2002; van der Graaf, 2020) who recommend the implementation of such opportunities for children.

6.7.3 Generalization of the Findings

The matching of the pre-tests and post-tests was performed for only 130 children out of 299. More specifically, no post-tests were collected for the specialized education type because they all participated in the 1x90 minutes format. As they showed great interest in the hands-on nature of the workshop, a particular attention should be set on this audience in the future. Also, the quality of the data collected with the 15 children enrolled in a differentiated education program is lower as well. This was expected since we observed that they were much less assiduous while completing the questionnaires. Although more workshop sessions would be needed to confirm this, it suggests that other data collection methods should be used in order to assess the workshop with this audience. Thus, in order to generalize the findings to our whole target group, more data would be needed from children in specialized education and from children in first and third secondary, for all education types, possibly involving other data collection methods.

6.7.4 External Factors

At the time the in-school sessions of the workshop were organized, one particularly recurring theme in the news was climate change and youth mobilization for climate (Napawan et al., 2017). This appeared to be somewhat reflected in the questionnaire answers, judging by the prominence of the environment dimension compared to the others. The results of the workshop might have slightly differed in that regard, had the news context been different. However, we cannot precisely assess the impact on the results.

6.7.5 Validation of the Tangible Interaction Table

One constraint for the development of the tangible interaction table was to reuse an existing reacTIVision table in order to provide multiple activities on the same piece of hardware. However, the table is located on campus site and access to the premises has been restricted since March 2020 due to COVID-19. Therefore, it was not possible to deploy the software on the physical table. When deploying the application on the hardware in the future, adjustments regarding e.g. performance and fiducial marker size for detection might be necessary. Without running the software on the table and without having access to end-users due to the pandemic, it was also impossible to conduct a user-based evaluation of the proposal. After having performed the aforementioned deployment adjustments, a two-part end-user evaluation should be conducted. First, a controlled study to assess the ease of use of the table and the clarity of the impact visualizations. Indeed, the design of the visual representation was chosen without involving teachers nor children, and is therefore an essential aspect to evaluate before the field study. Second, a field study to assess the integration of the table into the whole workshop, with a comparison against the results reported for the original workshop.

6.8 Conclusion

Citizens are more and more expected to participate in the smart city. However, due to the multiplicity of definitions and of discourses around it, the mere concept of "participation in the smart city" remains obscure to the larger public. It is therefore essential to educate the public to this concept, especially younger citizens aged 12 to 14, as they are key stakeholders to take into account in the smart city design, although they are often left behind in practice. At the same time, a recent important educational reform in Belgium requires that topics related to technology and democracy are discussed with children aged 5-15, which makes participation in smart cities especially relevant to be addressed in school. Therefore, the goal of this chapter is to provide resources for secondary teachers in order to help them discuss participation in smart cities in their classes. This goal was pursued by developing, evaluating, and refining an in-class workshop aiming to introduce the participatory smart city to children.

The workshop, built following the design science methodology, consists in (1) a discussion around the six smart city dimensions illustrated with real-life examples, (2) the collaborative construction of a city model that serves as work support, the identification of issues in the built mock city and of methods for asking citizens' opinion on these issues, and (3) the development of a voting system using a novice-level programming interface. It was tested as in-class activity with 299 children from several different schools.

Regarding the education to the participatory smart city concept (RQ1b), the results show that the workshop was successful in shifting the children's vision of the smart city from a solely technology-based to one where technology is at the service of citizens and is useful to solve issues faced by cities. During the sessions, children showed enthusiasm toward the proposed activity and critical thinking, especially when discussing participation methods. It shows that smart cities and citizen participation are concepts that can be discussed in a meaningful way with children. The positive and negative points of the workshop raised by children in the evaluation allowed identifying the elements children find desirable in such a workshop (RQ1a). In particular, it is important for children to have an opportunity to hear others' opinion and to share their own, to be able to question these opinions, and to learn new thing, all of this in a playful setting managing efficiently disagreements and conflicts.

The workshop evaluation led to the design of a second version of the workshop, supported by a tangible interaction table. It provides visual aids on the impact of buildings in the city model construction step and is destined to give more depth to the discussions throughout the workshop. It has yet to be evaluated with children, but we expect it to strengthen the playful aspect of the workshop while improving the discussion setting. In particular, the opportunity to question opinions is a desirable element in group discussions but it was not experienced to the desired extent in the workshop. By providing additional information in an accessible form, we hope to alleviate this issue by giving children concrete bases to challenges their opinions and well as others'.

CHAPTER 7

TACKLING BARRIER 2: IMPROVING ACCESS TO USABLE DATA

7.1 General Introduction

This chapter presents the research conducted to tackle the second barrier, namely the access to usable data needed for participation. Indeed, in order to involve citizens on a given matter, it is necessary for them to be informed first. For example, data about air quality is needed to take appropriate decisions regarding environmental policies to be implemented in a city. In the exploration of this barrier, we distinguish between two groups of citizens, namely experts and lay citizens. Expert citizens have technical and domain skills that lay citizens do not have. Therefore, they do not approach working with OGD in the same way as lay citizens, and they are expected to have different requirements toward the online portals that provide this data compared to lay citizens. As explained in Section 2, previous literature has put much more emphasis on the use of OGD and the requirements of expert citizens, and has set aside lay citizens. The requirements of lay citizens toward OGD portals and how they compare to those of expert citizens were consequently not described in detail in existing works (Research Gap 2, Challenge for Practice 2).

Research Gap 2: No detailed list of citizens' requirements regarding OGD portals extracted from a user study.
Challenge for Practice 2: OGD use by citizens remains low in practice, there is a need to determine whether current OGD portals are adapted to citizens' needs, and, if appropriate, to provide leads for improvement in order to increase their use.

Understanding the requirements of both expert and lay citizens is however a necessary step to address Barrier 2. Logically, it is needed to know citizens' requirements in order to provide them data in way that meets these requirements. It was therefore the first step we undertook. We achieved this by conducting interviews with 20 citizens which led to a list of 25 requirements, some shared by expert and lay citizens, others being specific to one group. The opportunity to enrich the findings related to expert citizens was given to us by a class project completed by 30 data science students (i.e. thus, considered as experts) that involved the use of OGD portals. Through a questionnaire and interviews, we elicited the impediments experienced by these students in their use of OGD portals. Among these portals is the one we relied on to collect citizens' requirements. The impediments were identified from a real-scale OGD use project and therefore shed a more practical light on the expert citizens' requirements.

The findings showed that important improvements to current OGD portals are needed to meet lay citizens' requirements. One of these requirements refers to the need of visualizations to understand the data more easily. Expert citizens are also interested in visualizations, however not for the same purpose as lay citizens. We therefore dug deeper in this direction, with a special emphasis on intra-city mobility data. Mobility was chosen because it is a theme of high interest for Belgian citizens (Pouleur et al., 2018; Lago et al., 2019), and it was restricted to the intra-city level for the sake of consistency with the smart city focus of this thesis. Instead of developing visualizations specific to a few datasets, our goal was to provide more general insights on mobility data visualization. We therefore conducted a systematic literature review to survey the existing works on intra-city mobility data visualization. It gives a complete overview of the intra-city mobility visualization approaches published in scientific literature, and can therefore be useful for developing visualizations of any OGD dataset on mobility.

7.1.1 Publications

The content of this chapter is based on the following scientific publications:

Anthony Simonofski, Antoine Clarinval, Wafa Hammedi, and Anneke Zuiderwijk. Tailoring open government data portals for lay citizens: A gamification theory approach. **International of Information Management**, 2021a. Under review

- This article presents a detailed list of citizens' requirements toward OGD portals obtained from 20 interviews with experts and lay citizens, as well as an OGD portal prototype implementing gamification mechanisms to address lay citizens' requirements. An evaluation of the prototype with 10 citizens showed that most of the gamification mechanisms proved useful to address the requirements, and that badges were the best received mechanism.

Jonathan Crusoe, Anthony Simonofski, Antoine Clarinval, and Elisabeth Gebka. The impact of impediments on open government data use: insights from users. In **Proceedings of the International Conference on Research Challenges in Information Science**, pages 1–12. Institute of Electrical and Electronics Engineers, 2019

- This article presents a mixed-methods study on the impediments faced by expert users when exploiting OGD. Through a questionnaire distributed to

30 students and 9 interviews, the article found that the most severe barriers to OGD data use were related to finding a value-adding project idea, data metadata and data quality, variations in data availability, and the integration of datasets.

Antoine Clarinval and Bruno Dumas. Intra-city traffic data visualization: A systematic literature review. **IEEE Transactions on Intelligent Transportation Systems**, ahead-of-print, 2021

- This article presents a systematic literature review of 146 works proposing intra-city traffic data analysis tools, destined to lay and expert users. It documents trends and research gaps in terms of domain, data source, visualization techniques, and evaluation. It is useful for researchers aiming to address research gaps in the field as well as a guide for developers to choose the most appropriate visualization techniques for their data and target users.

7.1.2 Outline

This chapter is structured as follows. Section 7.2 presents the requirements of citizens toward OGD portals. Section 7.3 details the impediments we identified from the OGD use of expert citizens. Section 7.4 gives an overview of the intra-city mobility data visualization approaches published in scientific literature. The methodology and limitations related to each of these three contributions are described in detail in their respective section. Recommendations for OGD publishers and for portal developers were derived from these works and are presented in Section 7.5. Limitations pertaining to the data collection activities are addressed in Section 7.6 Finally, Section 7.7 closes the chapter by summarizing its contributions and discussing how they contribute to its research questions of interest.

7.2 Citizens' Requirements Toward OGD Portals

In this section, we present the requirements toward OGD portals we identified from interviews conducted with citizens. We distinguish between expert and lay citizens and provide a list of requirements for both groups, showing which are shared, which are specific to one group, and especially which are conflicting. These insights are useful for practitioners. For portal developers, we show how citizens' requirements can be translated into specific features of OGD portals. For OGD publishers, we discuss the implications of our findings on the OGD publishing approach.

The methodology we followed to identify the requirements is presented in Section 7.2.1. The complete list of requirements is provided in Section 7.2.2, along with a discussion of each requirement fueled by the qualitative insights from the interviews.

7.2.1 Methodology

The research process we followed is represented in Figure 7.1. In order to identify the requirements of experts and lay citizens, we chose to perform semi-structured interviews. To recruit lay citizens, we wanted to identify people with low ICT and software development skills. To recruit expert citizens, we chose to focus on developers and researchers as they are the most prominent types of users of OGD portals whose requirements and impediments have been studied before (Beno et al., 2017). In both cases, we had to select participants who may be aware about OGD, who are interested to know more, and who are willing to participate in our study.

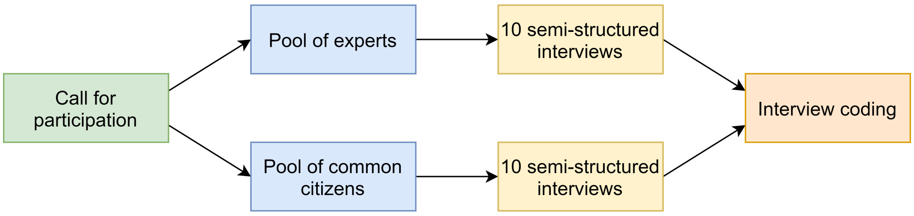


Figure 7.1: Research process for the identification of requirements toward OGD portals

To identify this pool of people, we sent out an open call for participation (through social media, mails, flyers and active recruiting on recreational areas, town halls, and supermarkets) and recruited people who gave the appropriate answers to several brief questions consistent with the approach to separate lay citizens from experts found in (Graves and Hendler, 2014). These identification questions can be found in Appendix D. This call was also sent to researchers from our university, to current and alumni data science students from the university, and to former OGD hackathon participants. Using people's self-evaluated ICT use and development skills on a 5-point Likert scale ranging from "very low" to "very high", we were able to differentiate experts from lay citizens. To be labeled as a lay citizen, neither development nor ICT use skills could be above the "medium" level. Then, among these two pools of possible respondents, we performed a judgment sampling to contact 10 interviewees in each group, in order to ensure the best representativeness possible in terms of skill levels, past experience with OGD, and occupation.

The interviews were held remotely using Microsoft Teams or Zoom. At the beginning of the interviews, we asked the participants open questions about their expectations on what an OGD portal should allow them to achieve. We chose to focus on municipal OGD portals as they are the closest to the citizen level and have been studied in the context of lay citizens' use before. We chose the OGD portal of Namur (Belgium) as object of study. Namur is one of the most advanced Walloon cities in terms of OGD provision and its portal was developed by OpenDataSoft, which is the most popular OGD portal provider in Belgium, and is therefore representative of the typical Belgian OGD portal. After that, we showed participants the municipal OGD portal of Namur[1] and gave them a few minutes to freely explore the portal. We encouraged them to perform think-aloud to understand their overall feeling. After the interviewees explored the OGD portal, we asked them to perform a usage scenario. The scenario consists in retrieving a specific information

[1]https://data.namur.be/pages/accueil/

on the portal, namely the budget allocated to libraries for the year 2019. Then, in order to complement the notes taken during the think-aloud phase, we asked the respondents additional questions. All these additional questions are included in the interview guide that can be consulted in Appendix D. This guide was pre-tested with one expert and one lay citizen. The main changes from these pre-tests concern the wording of questions to make them understandable by everyone. Furthermore, general questions about expectations were added as the respondents were easily willing to discuss their overall feeling about the portal. This research process allows a complete identification of requirements as the respondents are asked to give their insights about an ideal OGD portal in different ways: open expectation questions, free exploration of an existing portal and oral overall feedback, suggestion of a scenario to guide the use, specific questions related to the usage process.

Regarding the number of participants needed for this research, a well-recognized usability study shows that very few new findings emerge beyond ten users (Nielsen and Molich, 1990). The qualitative research literature gives no fixed evidence-based guideline on how many subjects to interview. Guest et al. (2006) rather recommend researchers to carry interviews until saturation is reached. Robinson (2014) reports that researchers conducting Interpretative Phenomenological Analysis should work with a sample size between three and sixteen. Guest et al. (2006) analyzed the transcripts of 60 interviews and reported reaching saturation at the 12th transcript, having uncovered 88% of the codes derived from the whole transcript set. Francis et al. (2010) mentioned the ten+three criterion, that is, ten interviews followed by three consecutive interviews without new insight. Based on these recommendations, we have conducted ten interviews (five with experts and five with lay citizens) to perform an intermediary analysis. We then carried out five extra interviews which allowed identifying two extra requirements and giving more depth to the requirements. The last five interviews confirmed the established findings. Therefore, the sample of twenty interviewees allowed reaching saturation in the requirements.

The interviews were analyzed with process and initial coding (Saldaña, 2015). The analysis started with summarizing the interviews and think-aloud transcripts and then recording them in a data memo. In order to code the data, we first skimmed the transcripts and highlighted relevant sentences based on the research objective. Second, we inserted the codes into a table divided according to the main phases of OGD use from (Crusoe and Ahlin, 2019) (i.e. start and motivation, search and evaluate, access and prepare, and aggregate and transform) and the analytical aspects from (Saez Martin et al., 2016) (i.e. functional, semantic, and content). Even though the user process from (Crusoe and Ahlin, 2019) relies on literature based on expert users (mostly developers), it constitutes a proxy to facilitate the analysis of lay citizens' use. When one of the two user groups made assumptions about the requirements of the other group (e.g. an interviewee with high development skills saying something would be tedious for him, if (s)he had no technical expertise), we did not consider them in our analysis.

The four phases of OGD use (Crusoe and Ahlin, 2019) are defined below:

- **Start and motivation**: The user needs to be aware and motivated to use OGD. In this phase, the user is trying to identify some way to use OGD.

- **Search and evaluate**: The user is searching on the Internet, OGD portals, and publishers' websites for promising data to use. Once promising data has been identified it can be evaluated to determine if it fits with the objectives of the *start and motivation* phase.
- **Access and prepare**: The user has the goal to acquire promising data and transform it into usable data.
- **Aggregate and transform**: The user has the objective to combine data and transform the new dataset into information, a product, or a service.

The definition for each analytical aspect from (Saez Martin et al., 2016) is provided as well:

- **Functional**: The functional perspective concerns the features allowing users to access information on the portal. More specifically, it covers the data search techniques, the organizational approach to data provision (i.e. indirect, direct, or both), the data provision itself (i.e. data can be consulted on the portal or downloaded), data visualization, and the features through which citizens can give feedback.
- **Semantic**: The semantic perspective covers the arrangement of the data in terms of structure and interoperability. In particular, this includes metadata, the level of open data following Tim Berners Lee's five-star model, multilingualism (i.e. whether the data is available only in the official language of the publisher or in other languages as well), and data format (i.e. human-readable formats such as PDF and Word, and machine-readable formats such as JSON, CSV, XML, or RDF).
- **Content**: The content perspective concerns the relevance of the published data and the information architecture. More precisely, the relevance is considered in terms of timeliness, accuracy, and quantity of published data. The information architecture covers the presence of a terms glossary, the structuring of datasets into categories, and the availability of filters.

7.2.2 List of Requirements

The requirements presented in this section were derived from interviews with the 20 citizens listed in Table 7.1. For each, this table provides their ID (which also indicates the group), ICT skills, development skills, occupation, and level of awareness about OGD. The average age of the interviewees is 34.

Table 7.2 summarizes the requirements identified in the interviews from the two citizen groups. For each requirement, the type (i.e. content, semantic or functional) and the sources (i.e. the ID of the interviewees from who we derived it) are noted.

In the following sections, qualitative insights about each requirement are provided. Furthermore, the main differences between the two citizen groups are highlighted.

Start and Motivation

Regarding the motivation before actually using the portal, the two groups share a number of requirements. First, they would all like more publicity to be done around

Table 7.1: Information about the interviewees. For each, the table provides their ID (**C = lay citizen and E = expert**), ICT skills, development skills, occupation, and level of awareness about OGD.

ID	Gender	ICT skills	Dev. skills	Occupation	Awareness about OGD
C1	M	medium	low	consultant	aware (never used)
C2	F	very low	very low	retired	not aware
C3	M	medium	very low	engineer	not aware
C4	F	low	very low	researcher	aware (never used)
C5	M	medium	low	law student	aware (never used)
C6	M	low	very low	teacher	not aware
C7	F	medium	low	NGO activist	aware (one use)
C8	M	low	very low	EU public agent	aware (one use)
C9	M	medium	very low	municipal public agent	not aware
C10	F	medium	low	school director	not aware
E1	F	very high	low	researcher	aware (used in university project)
E2	M	very high	very high	developer	aware (used in university project)
E3	M	high	high	researcher	aware (visited the portal)
E4	M	high	medium	geographer	aware (professional use)
E5	M	high	very high	developer	aware (used in hackathon)
E6	M	high	high	developer	aware (never used)
E7	F	very high	high	developer	aware (never used)
E8	M	high	medium	developer, researcher	aware (used in university project and professional use)
E9	M	very high	very high	developer	aware (used in university project)
E10	F	high	high	analyst	aware (used out of curiosity)

the portal (**R1**). The interviewees were either not aware of the existence of the portal (among the lay citizens, five were not aware), or reported not really knowing how the portal could be helpful for them. Lay citizens expect this publicity to be provided through social media, TV ads, flyers, the city website, radio, or sensitization workshops. Experts expected this publicity through targeted advertising on social media or mail campaigns. Several respondents emphasized that publicity should focus on successful reuses of OGD to show citizens concrete instances where OGD brings value. Some others reported that what is more important than publicity is to find the portal easily when looking for data (e.g. good referencing on Google). Second, both lay and expert citizens expect as much variety in the information found on the portal as possible, coming from the city's government, the public organizations (e.g. schools, libraries, universities) but also the private organizations within the city (**R2**).

Regarding the content of the datasets found on the portal, both groups have different expectations. Experts tend to expect a wide variety of datasets without a real preference for a certain category (**R4**). The main interest for them is that these datasets are raw and exploitable. On the other hand, lay citizens are more interested in informing themselves and more specifically in consulting datasets related to the transparency of the city (**R3**). Indeed, as shown in the scenario used to explore the portal, citizens want to access information about the city's functioning (budget, subventions, political reports). C1 mentions that these datasets are essential so that *"citizens can monitor the city and its representatives"* and C5 wants to check if *"the city implements the promises of the political campaigns."* This interest for transparency information was also observed from some experts, with e.g., E8 explained that *"if*

Table 7.2: Requirements identified from the 20 interviews (**R = requirement, C = lay citizen and E = expert**).

Phase	Requirements of lay citizens	Requirements of experts
Motivation	R1: More publicity around the goal and content of the portal (Functional) Source : C1,2,3,4,5,6,7,8,9,10 and E1,2,3,5,8,10	
	R2: Wide variety of information (Content) Source: C3,4,8,9,10 and E1,2,3,5,6,7,8,9,10	
	R3: Transparency and information datasets (Content) Source : C1,2,3,4,5,7,8,9,10 and E8	**R4: Niche reusable datasets (Content)** Source: E1,3,5,7,8,9,10
	R5: Information about the relevance of the portal on the welcome page (Functional) Source: C2,3,4,7,9	R6: Real-time data (Content) Source: E5,7,8,10
Search and evaluate	R7 : Efficient search engine (Functional) Source: C3,8,10 and E1,3,6,7,8,9,10	
	R8 : Structured and hierarchical categories (Functional) Source: C1,3,4,6,8,9,10 and E3,5,6,7,8,9,10	
	R9: Playful and attractive presentation of datasets (Functional) Source: C2,4,6,7,8,9	**R10: Itemized presentation of datasets (Functional)** Source: E2,3,5,6,7,8,9,10
	R11: Vulgarized content description (Semantic) Source: C1,2,3,4,5,7,8,9	**R12 : Technical descriptions (Semantic)** Source: E2,3,5,7,8,9
Access and prepare	R13: Data quality indicators (Semantic) Source : C1,5,9 and E1,2,3,6,7,8,9,10	
	R14: Human-readable format (Semantic) Source: C2,3,4,9,10	**R15: Machine-readable format (Semantic)** Source: E2,3,5,6,7,8,9,10
	R16: Export the data in relevant application (Functional) Source: C2,6,10 and E3	R17: Availability of APIs (Functional) Source: E2,3,5,6,7,8,10
Use and transform	R18: Proactive and personalized feedback mechanisms (Functional) Source : C3,6,9,10 and E1,2,4,6,7,8,9,10	
	R19: Customized visualizations (Functional) Source: C2,3,4,5,7,8,9,10	**R20: Raw datasets presented as tables (Functional)** Source: E1,2,3,5,6,7,8,9,10
	R21: Additional information and contact for each dataset (Functional) Source: C2,3,6,10	R22: Integration between datasets (Functional) Source: E2,3,5,9
	R23: Support during the use (Functional) Source: C2,4,6,7,8	R24: Technical tutorials and documentation (Functional) Source: E5,6,7
		R25 : Monitor changes in dataset (Functional) Source: E6,7,8
		R26: Contribute new data (Content) Source: E6,8

politicians highlight an evolution, it is important to have numbers to check their claim." However, conversely to lay citizens, experts want this transparency data to be published in a reusable format, and experts show interest in a wider range of datasets, as long as they can exploit them in applications. Some lay citizens also thought of the OGD portal as a single point of access information portal about the city with information they could not find elsewhere (e.g. location of public arts, pollution data). For instance, most of the lay citizens were not interested in COVID-related data as this information can be accessed through other websites or traditional media. Some lay citizens, such as C6, noted that the website should have an added value compared to the magazine issued by the city and distributed through traditional mail, either in term of content or in term of further possible analysis. C9 mentioned that he would not use an OGD portal for his city, as he already reads the municipal newspaper and has little needs for information. He, however, noted that the portal has an interest for citizens that are not from the city and have less knowledge of it. Whereas experts tend to use the data in applications or for scientific purposes, lay citizens will use them for information purposes to, as C5 puts it, *"support an argument where I lack data and where this data is not easily findable through other means."* Furthermore, as C7 expresses it, this data is *"necessary to make conscious choice in elections"* and C8 adds that it should *"ultimately enable him to participate in public life."* These different expectations for datasets lead us to formulate our first key difference between requirements: Lay citizens focus on transparency and information datasets whereas experts expect niche reusable datasets (**R3** vs **R4**).

Additionally, lay citizens would expect the relevance of the portals to be highlighted to them on the welcome page of the website through success stories of reuse by other lay citizens, use scenarios for the portal formulated as *"I search for ..."* or a *"dataset of the day"* (**R5**). Also, experts expect real-time data to be provided as much as possible on the portal to increase their exploitability (**R6**).

Search and Evaluate

Concerning the search phase of OGD use, both lay citizens and experts also share a number of requirements. First, they all expect an efficient search engine to access the datasets (**R7**). When using the engine on the portal of Namur, several users were not satisfied about the accuracy of the returned datasets. For instance, C3 searched for the phrase *"library budget"* but no dataset was returned as no dataset includes both *"library"* and *"budget"* in its title. Consequently, a vast majority of interviewees would like the search engine to search the titles and descriptions of the datasets but also the content of the datasets. Furthermore, interviewees would like to have automated suggestions of keywords when typing in the engine. Some experts suggested more advanced search features relying e.g., on elasticsearch or Boolean operators. The use of an efficient search engine is helpful when the users know which dataset they want to access. However, when freely exploring the portal, both groups expect structured and hierarchical categories to present the data (**R8**). The categories on the portal of Namur were satisfactory (e.g. mobility, governance, health) but additional subcategories are essential to allow an efficient browsing. For example, E3 suggested a sub-category of mobility data focusing on bike traffic. Several respondents, such as C5 and E8, mentioned that some datasets should belong to several categories.

Lay citizens would like this presentation of categories to be the default landing data page whereas the experts are satisfied with the presentation of datasets as a technical itemized list (**R10**). Furthermore, some lay citizens were discouraged by the presentation of datasets as a list that seems destined to *"IT people,"* as C2 states. Indeed, out of the 10 lay citizens, only 4 managed to access the searched dataset. As C2 puts it, she expects more *"attractive, playful, interactive and colorful"* interface to explore the datasets. C4 expected a *"visual map with logos representing the datasets on it, inviting her to explore them"* (**R9**). C8 mentioned *"an overload of information."* C9 felt overwhelmed with the displayed list of datasets and explained that *"there is too much stuff."* Thus, we formulate our second key difference: Lay citizens expect a playful interface to explore the datasets whereas the experts expect a neutral interface (**R9** vs **R10**).

Regarding the descriptions of the datasets returned after a search, the two groups have different requirements. Lay citizens expect a vulgarized and clear description about the content of the datasets, with examples and visual aids such as logos if possible (**R11**). This information is, as C7 mentioned it, *"essential to have contextualization of the data."* C9 mentioned that the technical information besides the title and description of datasets is useless and that *"it is nice to visualize on a map."* Although less disrupted by this additional information, C10 did not see much interest in them and explained that *"there are things that are not interesting for everybody but that they are forced to include, such as the license."* Experts expect a technical description of the datasets with information such as licenses, list of data attributes, and number of data entries (**R12**). This is the third main difference in requirements: Lay citizens expect vulgarized content descriptions of the datasets whereas experts expect concise technical descriptions (**R11** vs **R12**).

Access and Prepare

Regarding the access and the download of datasets, both groups expect data quality indicators for each dataset on the portal (**R13**). Indeed, they expect information about the data sources, the number of updates, and the possible missing data. In the case of experts, they have to download the datasets, as E5 puts it, to *"realize their utility for an application,"* which is *"a waste of time."* This lack of indicators can lead to, as C1 expresses it, *"a lack of trust in the datasets, like the city has something to hide."* Although both groups agree that data quality is essential and that indicators should be present, they have different views of what quality data is. For lay citizens, data of quality is data that can serve a purpose, *"data that can answer questions anyone could have"* as C9 puts it. Experts evaluate quality based on technical characteristics of the dataset such as the number of missing values, the absence of duplicate values, the absence of encoding errors, having a sufficient number of instances, uniformity (e.g. consistency in the space granularity), having all the values of a column following the same data format. Thus, when evaluating the quality of data, experts assess its exploitability and the severity of the data cleaning issues they will likely face when preparing the data for their applications. Several experts mentioned that the interest of having visualizations on the portal is to assist them in evaluating data quality issues. For example, it is easy to spot missing values and uniformity issues on a map.

Experts and lay citizens do not expect the same data format for the datasets. Experts expect machine-readable formats such as CSV, JSON, or shapefiles for geographical data (**R14**), while lay citizens expect data in a human-readable format with qualitative information such as Excel, PDF, or Word (**R15**). In most cases, lay citizens do not even expect to download a dataset but simply want to consult it on a webpage of the portal. The fourth identified difference is thus formulated as: Lay citizens expect human-readable format whereas experts expect machine-readable format (**R14** vs **R15**).

In some cases, lay citizens would still like to export the relevant data in a dedicated application (**R16**). One citizen wanted to export the information about public arts in Google Maps. C10, as he is experienced with Excel, wanted to export a whole dataset as an Excel spreadsheet to run analyses and generate graphs with Excel. Most of the experts also mentioned the APIs as being key elements to be found on the portal to facilitate the export of data in applications (**R17**).

Use and Transform

Most interviewees from both groups would not give feedback instinctively to the portal (about the content or the features). However, they mentioned that having personalized contact information on a dedicated tab on the website would increase their chance to give feedback. Furthermore, proactively asking their opinion through mails or dedicated workshops would be the ideal way to give feedback for them (**R18**). Overall, both groups found that the feedback feature on the portal was useful, with C10 actually wanting to send feedback during the interview to report a bug he had spotted. Lay citizens considered the feedback form as sufficient, however experts would expect to be able to provide more contextual feedback. They suggested adding a feedback button specific to each dataset with a predefined list of issues to pick from.

The main difference in requirements between lay citizens and experts relates to the presentation of the datasets. Experts are satisfied with a presentation as a table as it is structured and allows for a quick overview of the content and structure of the datasets (**R20**). However, lay citizens expect customized visualizations depending on the datasets (**R19**) (e.g. pie charts for budgets or maps for pathways). They would like to have a default visualization and additional buttons with clear labels such as *"overall distribution"* or *"evolution over time"* and to have the according visualization presented to them to have dynamic information instead of static. These analysis features constitute for lay citizens the added value of the website compared to the city's magazine they receive each trimester. It must be noted that some lay citizens (often with medium ICT skills such as C1, C3, and C10) are satisfied with the presentation as a table, especially for quantitative data, as long as visualizations are available. It must also be noted that visualizations are nice-to-have for some experts as well but in most cases, they would build their own customized visualizations. Experts use the visualizations on the portal for a different purpose than lay citizens, that is, to assess the quality of the data. The last key difference is thus formulated as follows: Lay citizens expect information through visualizations whereas experts expect raw data (**R19** vs **R20**).

Additionally, some lay citizens would like to have more information about each element of the dataset and to give their opinion to the city after examining the datasets (**R21**). For instance, C2, when examining the budgets for culture in Namur, would have liked to click on a specific line (e.g. representing an event) and to ask the relevant political representative about it through the portal directly. Experts would also like to integrate several datasets directly on the portal (**R22**). E3 mentioned that *"much of data has an interest only if it can be linked together."* E9 explained that it is important for datasets to have consistency in the space granularity as the location is often used as key to link several datasets together, and that issues in that regard can make the data not usable altogether. For instance, plotting them together on a map with several layers is an important feature that can support further analysis. Regarding support tools, most of the lay citizens mentioned that they would not spend time looking into *"tedious"* tutorials or reading information about the use of the portal. The interface, as explained above in R9, must be easy to use naturally. However, if the lay citizens have specific questions related to the use of the portal, they would like to find support easily during their use through clickable information points, chatbots, or blogs connecting the users' community (**R23**). On the other hand, the experts are happy with the presence of technical tutorials and documentation on the website (**R24**).

Lastly, some experts mentioned wanting to monitor the changes in some specific datasets, by being able to *"subscribe"* to it on the portal, or by having the add date of each instance in the datasets (**R25**). Also, they believe that users should be able to contribute data on the portal, which would allow several data sources to exist for the same information and thus make it possible to choose the most suited to their needs (**R26**).

7.3 Expert Citizens' OGD Use Impediments

In this section, we delve deeper into the requirements of expert citizens by confronting them to the impediments they reported experiencing when conducting an OGD use project. Such insights are interesting for completing the requirements identified in the previous section. Indeed, they were derived from an interview and a scenario consisting in retrieving data. In the project considered in this section, the OGD use involves retrieving data as well but goes far beyond. Furthermore, the severity of the impediments experienced can give an exploratory indication of the importance attached to some requirements. This perspective is indeed absent from the list provided in the previous section.

This section is organized as follows. Section 7.3.1 discusses the context that frames the studied OGD use project and details the data collection and analysis processes. The identified impediments are presented in Section 7.3.2. They are ranked by severity and discussed in light with the qualitative insights we collected. Lastly, Section 7.3.3 discusses the impediments further in line with the experts' requirements identified in the previous section.

7.3.1 Methodology

Context

In order to collect information about the impediments that users can experience when using OGD, we examined a specific data science project conducted by 30 master's students between October and December 2018. 22 of them have a management background, 4 study computer science, and 4 mathematics. These students have high digital literacy and are thus representative of the typical OGD expert user population. They were asked to use OGD from the portals of Namur[2], London[3], Paris[4] or New- York[5] to develop an application valuable for the citizens or the public servants working in the administration. The guidelines for the project were reduced to a minimum to stimulate creativity and the real-life use of the OGD portals. The following constraint was nonetheless imposed on the students. The output of their project should be transferable to the city of Namur, provided that the city acquires and makes available the necessary data. In this way, the projects' outputs consisted not only of solutions directly applicable to Namur but also of prospects valuable for the city officials of Namur.

Data Collection

To collect data from the data science students, we followed a mixed-method approach that combines a questionnaire and semi-structured interviews. Johnson et al. (2007) argue that a combination of methods allows having informative, complete, balanced, and useful research results. We chose this combination of methods in order to reach a complete view of the impediments experienced by users. The quantitative insights helped us to understand the importance of impediments whereas the qualitative insights gave specific details about the impediments. Furthermore, the quantitative insights helped us to frame the interview guide in order to ask questions about the most important reported impediments.

Questionnaire We structured the questionnaire based on the user process previously detailed in (Crusoe and Ahlin, 2019). This process is divided into four phases that are described in Table 7.3. Figure 7.2 summarizes the four phases and the three constructs we measured. The first construct we measured is **resource allocation**. It evaluates the amount of time allocated and people involved for each phase. Respondents were asked to rank the four phases according to the time it took to complete them, and also according to how much they contributed. This information can be used to assess the impact of impediments in terms of time consumption. Then, the **perceived usefulness** construct evaluates the extend to which the phases of the process are perceived as useful for the project output by the students. A 5-point Likert scale ranging from "Not useful at all" to "Very useful" was used. This information is useful to prioritize the impediments to be tackled. Indeed, if some activities are perceived by users as most essential for their output, alleviating the impediments related to these should be done with a higher priority. Lastly, we measured the **perceived difficulty** on a 5-point Likert scale. More precisely, the questionnaire measures the severity of the impediments reported in (Crusoe and Ahlin, 2019). We used the term "barrier" in the questions for better understandability of the questions. Again, this information is useful to prioritize the impediments to be tackled. Those

[2] https://data.namur.be/explore/
[3] https://data.london.gov.uk/
[4] https://opendata.paris.fr/explore/
[5] https://opendata.cityofnewyork.us/

Table 7.3: User process framework describing the use of OGD by experts from (Crusoe and Ahlin, 2019).

Phase	Activities	Sources of impediments
Start and motivation	Discover OGD and identify where OGD can be used.	Public advertisement, understand how OGD can be used, and examples of use.
Search and evaluate	Engine searching, portal searching, browsing the publisher's website, pre-evaluate data on an OGD portal, and evaluate data on the publisher's website.	Search features, presentation of search results, metadata, must download the data to evaluate, tools to explore and analyze data, language, and licences.
Access and prepare	Manual access (e.g. download PDF), automated access (e.g. API), and prepare data.	Access method, documentation, filtering, data format, data quality, accessibility, registration, and support.
Aggregate and transform	Aggregate data, analyze data for information, and develop a product or a service.	Combine data, quality variations, availability variations, supporting tools, longitudinal data, data infrastructure, and domain knowledge.

that cause the most severe hindrance should be addressed with a higher priority. In order to measure the perceived difficulty, the severity of the impediments was evaluated by relying on the instrument previously described in (Beno et al., 2017):

(i) **Not a barrier**: it was easy to use the data.
(ii) **Somewhat of a barrier**: it was still possible to use the data.
(iii) **Moderate barrier**: it was difficult to use the data.
(iv) **Serious barrier**: it was extremely difficult to use the data.
(v) **Extreme barrier**: it was impossible to use the data.

Besides the questions related to the three constructs, the questionnaire includes contextual questions on the respondents' background, the skills they acquired for their project, and their confidence with programming, data analysis, and OGD portals. The questionnaire ends with a broad open question, allowing respondents to share insights on the class project and OGD in general. The complete questionnaire is available in Appendix C.

Interviews In order to complete and better analyze the results from the questionnaire, we conducted in-depth interviews with nine students. We applied quota sampling to select the interviewees. The quota was based on students' study orientation (computer science, management, or mathematics) to ensure representativeness. We limited our study to nine interviews to respect the sampling method. Indeed, the quota sampling implies interviewing the same number of student for each background. Only four mathematics students were involved in the whole project, three of whom were available for an interview because of their limited availability due to

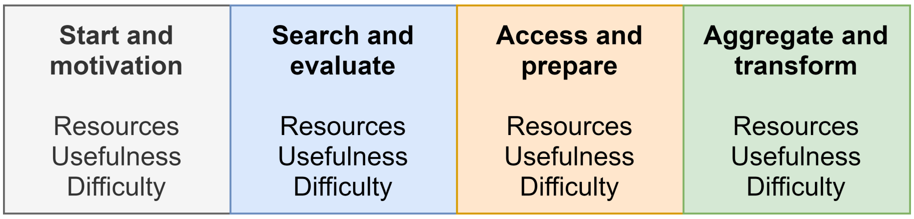


Figure 7.2: User process framework describing the use of OGD by experts from (Crusoe and Ahlin, 2019). The questionnaire measures the *perceived difficulty*, the *resource allocation*, and the *perceived usefulness*.

the OGD project ending only a few weeks before the exam session. We therefore interviewed nine students, that is, three per background.

The structure of the interview guide is similar to that of the questionnaire. The interview guide starts with introductory questions on the overall user process, as we were interested to compare the user process framework with the activities conducted by students in their project. Moreover, the most severe impediments from each phase that were reported in the questionnaire results were discussed with the interviewees in order to collect deeper insights. The interview guide ends with retrospective questions on the project. This latter part includes, among other things, questions regarding the students' motivation to use OGD again and what support they want from OGD publishers. The complete interview guide is available in Appendix C.

Data Analysis

Questionnaire The questionnaire data consist of items evaluated on a 5-point Likert scale for the *perceived difficulty* and the *perceived usefulness*. In order to have a central tendency measure for each of these items, the median was computed (Boone and Boone, 2012). As for the *resource allocation* construct, it was measured by a ranking exercise on the four phases. In order to obtain a representative ranking, the mode was computed for each phase.

Interviews The interviews were analyzed with process and initial coding (Saldaña, 2015). The analysis started with summarizing the interviews and then recording them in a data memo. Afterward, four researchers divided the data between each other based on the user process. Each researcher coded a specific phase for each interview. The coding started with skimming the interview to get a sense of the whole, then important sentences were highlighted based on the research objective, and the highlights were coded using short sentences to retain context and conceptual relations. The codes were then inserted into a table divided according to the interviewees and process phases. As the analysis progressed, researchers could write analytic notes to record insights and thoughts. All the coding was conducted in the same cloud-based document, as such the researchers could follow each other's coding process and verify codes if needed.

Table 7.4: Summary of the quantitative findings regarding the perceived difficulty, the resource allocation, and the perceived usefulness, for each phase of the OGD use process.

Phase	**Perceived difficulty**	**Resource allocation**	**Perceived usefulness**
Motivation and start	Find an idea	4 (least)	Useful
Search and evaluate	Quality of metadata	3	Useful
Access and prepare	Data quality	2	Useful
Aggregate and transform	Data cannot be combined Data availability varies No longitudinal data	1 (most)	Very useful

7.3.2 List of Impediments

In the following, the quantitative results from the questionnaire regarding the three measured constructs are successively presented. Then, the discussion on the *perceived difficulty* is refined with the qualitative insights from the interviews. The findings from the questionnaire regarding the constructs are summarized in Table 7.4.

Perceived Difficulty

Figure 7.3 presents the results from the questionnaire regarding the severity of the impediments. The severity was computed as the median answer of the 30 respondents. None of the process phases is exempt from moderate barriers (median = 3). Hence, the users experienced difficulties in every phase, since a moderate barrier indicates that the use of data was difficult. In the *start and motivation* phase, users struggled to find an idea for OGD use. In the *search and evaluate* phase, they faced issues with metadata (i.e. information about a dataset, such as collection methods and descriptions). In the *access and prepare* phase, the problems lied in the quality of the data. Lastly, in the *aggregate and transform* phase, users had trouble with combining data, the variation in data availability, and complained about the lack of longitudinal data.

The questionnaire results also show that some potential impediments were not a barrier for the users (median = 1). It is, however, worth noting that these are concentrated in the *search and evaluate* and *access and prepare* phases. Hence, every potential impediment in the questionnaire for the *motivation and start* and the *aggregate and transform* phases was a barrier to some extent.

Resource Allocation

In the questionnaire, respondents were asked to rank the four phases by how much time they had invested in each. The least time-consuming phase was the *motiva-*

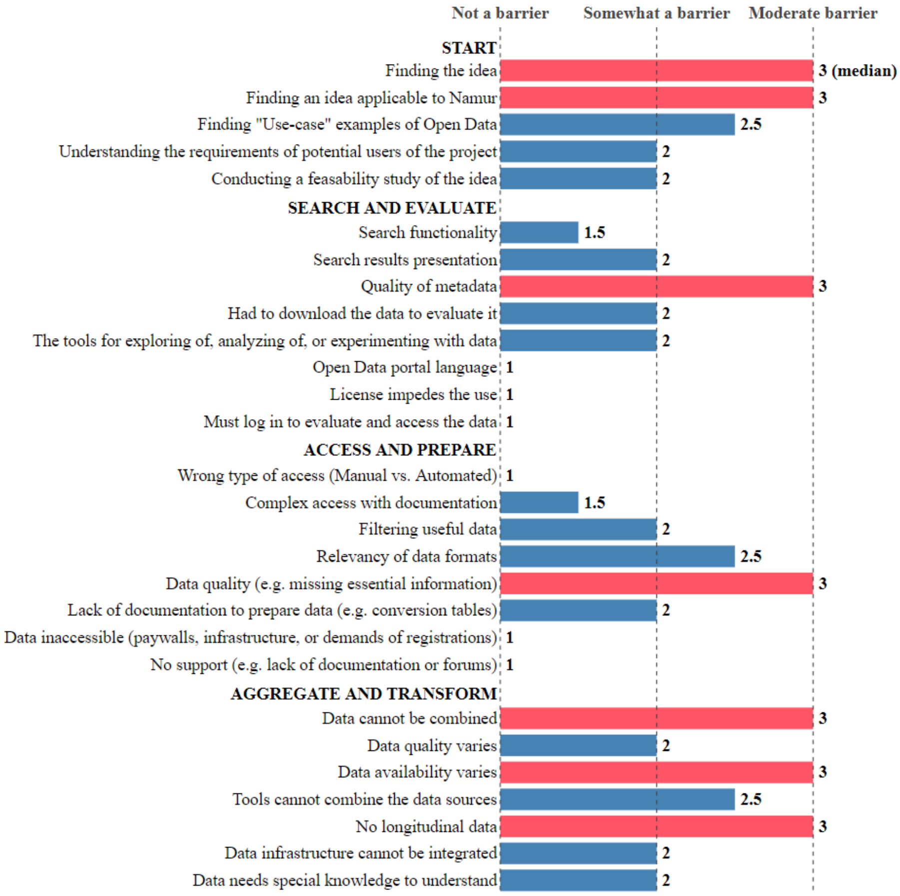


Figure 7.3: Median for each impediment computed from the questionnaire results. The impediments colored in red are the most severe for their respective phase.

tion and start, followed by *search and evaluate, access and prepare*, and, lastly, by *aggregate and transform*, which is therefore the most time-consuming phase. The perceived individual contribution reported by the respondents follows this trend as well. The resource allocation per phase thus appears to increase throughout the process.

Furthermore, 26 of the 30 users reported having to learn new skills required for the success of their project. This self-development was expected since most of the users have a management background. The learned skills were mainly about web-oriented languages (Javascript, CSS, HTML, web libraries), Python, and how to connect a Python script and a web page (the Flask framework was recurrent for this matter). This acquisition is one factor contributing to the high time allocation of the late phases.

Perceived Usefulness

All phases were perceived as useful (median ≥ 2). The *aggregate and transform* phase was considered as very useful (median = 1). This outcome was expected, since the final output of the project is delivered at this phase, and the project is graded.

Qualitative Insights on Perceived Difficulty

In the following section, qualitative insights on impediments are presented following the phases of the user process framework.

Motivation and start The in-depth interviews revealed that the process of ideation was mainly based on the personal needs, uses, or intuitions of the users. Then, users visited the OGD portals, looking for datasets, and, as a result, changed or gave up their first ideas as data was missing. Sometimes this was repeated several times. This process of divergence and convergence, using creative techniques like mind-maps and brainstorming, was constrained by the availability of datasets in the chosen portals. As one user expressed: *"We've got a lot of ideas by looking at the datasets' name in 20 to 30 minutes of brainstorming. But the difficulty was to realize them. When we opened the datasets, important information was missing. Thus, we had to give up some ideas."*

All the interviewees faced this issue, and it shaped their output. Two teams of users started directly from the OGD portal and with the combination of datasets to save time. Seven of them mentioned the limited number of datasets as a major constraint for their project development. They said they had more innovative ideas than data to develop them. As one user expressed: *"I have the impression that the OGD portals were pretty empty in valuable datasets, or the datasets could be usefully combined with other sets that we didn't have."*

Users were frustrated that they could not exploit more than the city's OGD portal for their project since the data was too limited and they had little insights into Namur's challenges or priorities, citizens' needs, and market opportunities. The interviewees reported being discouraged by the abundance of existing apps, the lack of domain knowledge and given examples, the absence of precise demand, and the lack of useful datasets. As one user explained: *"it would have been helpful to have ideas from the citizens."*

Search and evaluate The interviews confirmed that the main impediments for the *search and evaluate* phase are in the *evaluate* activity. No interviewee reported issues with the interface of the OGD portals they used. They found that the portals were well-designed in this regard, confirming the findings of the requirements identification, and provided adequate features for searching data, such as filtering and suggestion of related datasets. The *evaluate* activity, however, was more challenging. The interviews confirmed that the main impediment is the lack or inadequacy of metadata, as observed when analyzing the questionnaire answers. Six users stated that they encountered issues with metadata. The interviews allowed us to refine this point, and uncovered that the *evaluation* of data can be examined at different granularity levels.

First, three users faced issues with the **data features** (i.e. columns in a dataset) names, which they found uninformative and badly described. Unexplained columns meant that the user could not use the dataset. For example, one user encountered a population census dataset holding a number of girls and a number of women and he had to make calculations with census data to determine whether the girls are also counted as women. Another user complained: "*In our datasets, half to three-quarters of the features we didn't know what they meant, and it wasn't explained anywhere [...] We completely ignored these columns.*"

Second, metadata at the **dataset** level were mentioned by three interviewees as an issue. One user was disappointed that "*some dataset titles are awesome, but there is nothing exploitable in them.*" In order to compensate for appropriate metadata, users had to resort to other evaluation methods. One user downloaded the data for further examination. Even worse, one user reported feeling frustrated, as the lack of informative metadata prevented exploiting the full potential of the available data. On the other hand, one user used the API feature to explore a dataset. Nonetheless, some features offered by the portals were helpful in the evaluation of data. One user noted that the reuse examples comforted him with the potential of the data and increased his motivation to use data. Another user mentioned the usefulness of visualizations showing an overview of data as helpful.

Access and prepare The in-depth interviews allowed us to explore the data quality impediment reported in the questionnaire. On a general note, the data quality was very fluctuating across datasets. There was a lot of data in the datasets that three interviewees respectively qualified as "*missing,*" "*irrelevant,*" or "*corrupted.*" Two interviewees mentioned the lack of longitudinal data as the main impediment for regression analysis. Finally, a lack of consistency in the datasets was also reported by four interviewees. These impediments impacted the output of the work. One user noted the impact as *"because of the few relevant datasets our application was not as valuable as we wanted. Our application issues abnormal recommendations, such as: fewer trees will lead to better air quality!"*

No major issue was reported in terms of data formats as most of the datasets were available in JSON and CSV. Some case-to-case issues were still reported, such as some irrelevant geographic data formats and integers represented as string data.

Also, the interviewees experienced no major problem with the APIs (one API was missing, and some errors were present in the requests). However, three respondents declared they did not use the API but rather downloaded the data directly. This approach may reveal that they did not see the added value of using this channel to access the data. It indeed often seems faster for the users to just download data. The approach may also indicate that the users did not seek to develop a sustainable solution, which could be explained by the context of the project, which is a graded course.

Aggregate and transform For the *aggregation* activity, users can select specific datasets based on criteria, select columns in the dataset, merge datasets to fill out gaps, and use scripts to clean the data. Merging can be time-consuming and involve a "one at a time" error solving approach. As one user said: *"I spent a very large part of my time just on data aggregation since it was a monster mess."* For *transformation*, users can calculate averages, integrate data into web applications, think about the end-user experience, and seek support. There were some impediments in these activities. To make data combinable, sometimes keys needed renaming, data needed normalization as datasets were inconsistent (e.g. different metrics), and, in other occasions, several datasets had to be merged to form a complete dataset. As one user explained: *"[Datasets] didn't use the same way of localizing things. They all used neighborhood names, but the issue was that they didn't use the same neighborhood names. [...] It was nearly impossible to do the matching; they didn't use the same partitioning at all."*. In the worst case, data lacked unique identifiers, datasets could use different unique identifiers, or feedback could be hard to leave, making an increase in data quality unlikely. On the other hand, *transformation* could be impeded by slow data delivery, a need to add exceptions, and technical complexity. As a result, data needed more preparation to be combinable, which likely contributed to the high time consumption of this phase. One explanation is that when the users once started to transform data or combine data, they noted the work needed to prepare the data. Moreover, the in-depth interviews indicated that it was easier to use one dataset than several, or a single category of data (e.g. photos) than combining several.

7.3.3 Link with Expert Citizens' Requirements

When confronting the most severe impediments and the identified requirements for experts, a clear mapping appears. Each impediment gives an additional perspective on some requirements by describing the consequence of the portal failing to meet these requirements. Table 7.5 shows the mapping for each of the impediments characterized as "moderate barrier" (i.e. making it difficult to use the data) following the OGD use project.

The users explained that they had difficulties finding an interesting idea to implement with OGD. We can link this impediment to two requirements. First, the users noted that they have little knowledge of the citizens' problems that need to be addressed, which is one of the reasons why finding a project idea was so difficult for them. This is related to requirement R1, which calls for more publicity around the goal and the content of the portal. Indeed, one goal of OGD portals is to encourage the creation of applications of value for citizens, that is, applications that address an issue they face. Failing to emphasize this on the portal makes it difficult to create applications actually bringing added-value. The second reason explaining this impediment is that many ideas are not feasible with the datasets published on the portal. This is in direct link with requirement R2 (wide variety of information). The impediment shows that this variety is indeed needed for OGD users to develop a feasible idea, and that failing to achieve it can lead to users experiencing frustration.

Table 7.5: Relationship between the most severe impediments and the identified requirements.

Impediment	Requirements
Find an idea	More publicity around the goal and the content of the portal (R1) and Wide variety of information (R2)
Quality of metadata	Technical descriptions (R12)
Data quality	Data quality indicators (R13)
Data cannot be combined	Integration between datasets (R22)
Data availability varies	Real-time data (R6)
No longitudinal data	Monitor changes in dataset (R25)

The second impediment concerns the quality of the metadata (i.e. dataset title, column names, description of the data features, etc.). It is related to requirement R12 about the technical descriptions of datasets. Failing to meet this requirement impacts negatively the exploitability of the published datasets. The users reported facing incomplete and even misleading metadata, which again led to frustration and to the inability of using the data necessary to implement the idea defined in the *start and motivation* phase. As a result, some users had to backtrack, that is, go back to the first phase of the user process and come up with a new idea that fits the content of the portal rather than the issue they wanted to address.

The data quality impediment is linked to requirement R13, which calls for data quality indicators. Some users noted that they faced incomplete or corrupted data, which had a detrimental effect on the output of their project. One direct solution would be to allocate resources to the OGD publishing process so that more time can be invested into data cleansing upon publication. However, a recent study on publishing processes (Crusoe et al., 2020b) showed that the resources are sometimes limited in practice. Nonetheless, backtracking becomes problematic at such a late phase of the user process, and it is therefore essential to limit the damage regarding quality issues. The data quality indicators can bring an answer by helping users to detect early the quality issues that may impede the use of the data in the further phases. The interviews conducted for the requirements elicitation showed that visualizations are useful for expert users to assess data quality. In the OGD use project, some users mentioned that visualizations were useful to get an overview of data in the *search and evaluate* phase. Indeed, issues in data such as missing values can quickly be identified on a visual representation.

The impossibility of combining datasets is related to requirement R22, which concerns the integration between datasets. This impediment finds its root in the lack of common keys across datasets such as consistent geographic references. The absence of data features allowing an easy linkage between the dataset had a tremendous impact on the time invested by the users, who might have been discouraged to carry on the project altogether if it was not mandatory to validate a course.

The variation in data availability echoes requirement R6, which calls for real-time data. Indeed, the issue with availability that some users experienced in the project is that different datasets cover different timespans. In the project, this was detrimental to the accuracy of the analyses conducted on the datasets. While some efforts can be made on historical data to improve the timespan consistency, providing real-time updates on several datasets would ensure that they cover the same timespan and therefore alleviate the impediment.

Lastly, the lack of longitudinal data relates to requirement R25 (monitor changes in dataset). Longitudinal data is needed to study the evolution of variables and to compute prediction models. Providing users with a way to monitor changes in specific datasets, and providing these changes without overwriting the previous versions, would be helpful for these analyses.

It is interesting to observe that the most severe impediments concern the data in itself rather than the features of the OGD portal. This is consistent with what emerged from the interviews conducted with experts for the requirements identification. Although some features have room for improvement and others would be welcomed, the OGD portals are well-suited for expert citizens. From the results of the impediments elicitation, it appears that the activities depending on the portal rather than the data (e.g. search, access) did not cause any major issue.

7.4 Overview of Intra-City Mobility Data Visualization

An important feature for experts that was identified in the requirements elicitation and confirmed by the OGD use impediments is the visualization of data, which is useful to assess the quality of datasets. The presence of visualizations was also identified in the requirements for lay citizens (R19 in Table 7.2), and is confirmed by previous research (Puussaar et al., 2018) which showed that open data should be nicely presented for citizens to use it. Therefore, although useful for different purposes, OGD visualizations should be offered to both experts and lay citizens. Visualizations are already present in many OGD portals, but have room for improvement in order to fully meet the requirements. For example, the OGD portal of Namur relies on automated visualization generation, which can in some cases lead to visualizations from which it is hard to get information. Two illustrations are given in Figure 7.4, which shows the stacked bar chart visualization generated by default for the 2019 budget allocation, and in Figure 7.5, which shows the map visualization shown for the distribution of COVID-19 cases across municipalities. According to visualization good practices (Munzner, 2014), a simple bar chart with one bar per budget item and a choropleth map colored according to the number of cases would be better design choices.

Since improving the provision of data visualizations on OGD portals would benefit both lay and expert citizens, we dug deeper into this direction and developed a guide to help OGD portal developers to choose the most suited visual representations. In terms of scope, covering the full OGD spectrum is beyond the goal of this thesis. On the other hand, focusing on a few specific datasets would be a limited

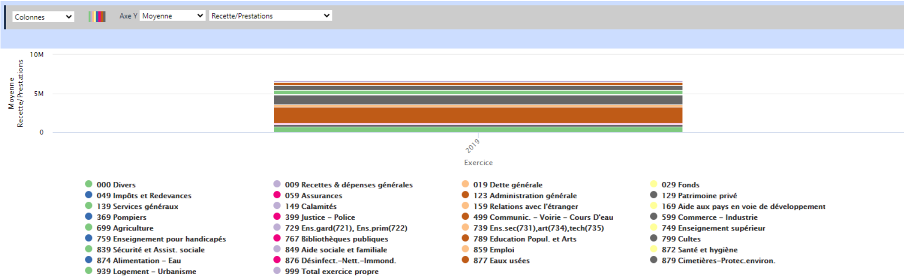


Figure 7.4: Stacked bar chart visualization generated by default on the OGD portal of Namur for the 2019 budget allocation

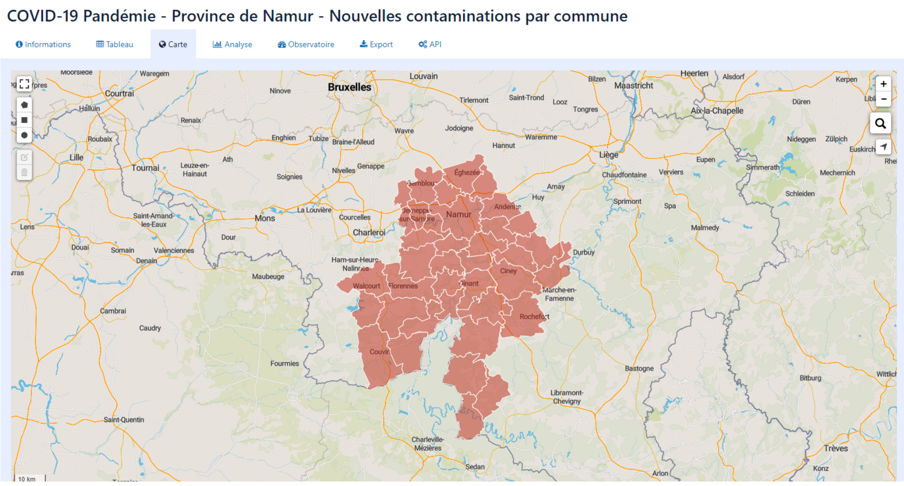


Figure 7.5: map visualization shown on the OGD portal of Namur for the distribution of COVID-19 cases across municipalities

contribution. Thus, the scope was set on one category of OGD, namely intra-city mobility as motivated at the start of this chapter. Mobility was chosen primarily due to the Wal-e-Cities MOB project, which has a focus set on mobility. It is also a theme of high interest for Belgian citizens (Pouleur et al., 2018; Lago et al., 2019). Mobility was restricted to the intra-city level for the sake of consistency with the smart city focus of the Wal-e-Cities project and of this thesis. Instead of developing visualizations specific to a few datasets, our goal was to provide more general insights on mobility data visualization. We therefore conducted a systematic literature review to survey the existing works on intra-city mobility data visualization. It gives a complete overview of the intra-city mobility visualization approaches published in scientific literature, and can therefore be useful for developing visualizations of any OGD dataset on mobility.

In order to elaborate this guide, we conducted a systematic literature review of intra-city traffic data visualizations that are destined to experts and/or lay citizens.

The guide describes the trends observed from the surveyed research works, such as the visualizations used to represent data for a given audience and for a given domain. Furthermore, all the information extracted to formulate these trends accompanies the guide. The interested reader can therefore retrieve all the works surveyed for a given audience, domain, data source, etc.

The methodology defined for the literature review is detailed in Section 7.4.1, structured according to the standard steps of a systematic literature review. The trends extracted from the surveyed articles are presented in Section 7.4.2 and illustrated with examples from the literature.

7.4.1 Methodology

The main steps of the systematic literature review methodology (Kitchenham and Charters, 2007; Kitchenham et al., 2015; Petersen et al., 2008) include discussing the need for a review, defining the research questions, defining a review protocol (i.e. search terms, digital libraries), selecting the relevant studies (i.e. inclusion and exclusion criteria), extracting data (i.e. extracting the relevant studies and categorization), assessing the completeness of the coverage of the review, and describing the dissemination mechanisms. Each of these steps is addressed in a dedicated section below.

Need for a Review

Traffic data visualization has greatly grown in importance in the past years. As a result, several works have been published to review existing research, structure the field, and propose avenues and recommendations for future research (see Table 7.9). Five of them are discussed below, in terms of how they classify existing research and the directions they propose. Afterward, we discuss why we needed to conduct an additional literature review for the purpose of this thesis.

In 2013, Andrienko and Andrienko (2013) structured research on visualizing the trajectories in space and time of discrete objects. The classification scheme they proposed holds four categories, differing from each other by their perspective on movement. First, in the *looking at trajectories* perspective, trajectories are regarded as atomic constructs. The second perspective is *looking inside trajectories*, which views trajectories as a set of points and segments. The third perspective, *bird's-eye view on movement*, aggregates trajectories. Finally, the *investigating movement in context* perspective studies the links between moving objects and their environment bytes. It is detailed in Table 7.6, an example is provided for each category for illustration purposes.

Two years later, Chen et al. (2015b) reviewed the tasks of visualization applied to traffic, the data types, the data pre-processing methods, and the visualization techniques. They proposed to structure the existing work on traffic visualization according to the represented variables into four categories. First, *time* variables represent the change over time of traffic-related constructs. Second, *space* variables describe the location in space of traffic-related constructs. The third variable type,

Table 7.6: Movement visualization classification from (Andrienko and Andrienko, 2013).

Category	Perspective	Example
Looking at trajectories	Trajectories are regarded as atomic constructs	Map showing all the trajectories describing people's movements in a city within a time frame
Looking inside trajectories	Trajectories are a set of points and segments	Map showing the density of moving objects alongside a trajectory
Bird's-eye view on movement	Aggregation of trajectories	Map showing the number of trajectories by district
Investigating movement in context	Links between the moving objects and their environment bytes	Map showing the trajectories with regard to the weather conditions of the considered time frame

Table 7.7: Traffic visualization classification from (Chen et al., 2015b).

Variable	Visualized constructs	Example
Time	Change over time of a traffic-related construct	Histogram showing how the average speed varies throughout the day
Space	Location in space of a traffic-related construct	Map showing the congested areas in a city at peak hours
Space-time	Change over time of a traffic-related construct that has a changing location in space	Space-time cube tracking the movements of a person throughout a working day
Multivariate	Any variable aside time and space	Parallel coordinates plot displaying traffic accidents with accident type, number of casualties, and number of vehicles involved

space-time, combines the two previous and describes the changes over time of traffic-related constructs that have a changing location in space. Finally, the *multivariate* type refers to any variable aside time and space. They are further detailed in Table 7.7, illustrative examples are provided as well.

Zheng et al. (2016) presented an overview of urban data visualization. Urban data includes but is not limited to traffic data. The way they structured their review of urban data visualization is analogous to (Chen et al., 2015b). They differentiated between visualization of *time*, *location*, and *multiple properties*. The latter covers spatio-temporal properties as well as any other variable. Location data is further refined into *point-based*, *line-based*, and *region-based* data.

The following year, Andrienko et al. (2017) published another survey of movement data visualization. They differentiated between *spatial event data* (i.e. data relating to a defined location in space), *trajectory data* (i.e. sequences of positions in space over time), and *space time series* (i.e. sequences of time-varying values regarding a defined location in space). Then, they organized the body of research in visualizing movement data into three categories. Unlike the classification schemes used in the other surveys brought up in this section, the categories they propose focus on why visualization is used, rather than the visualized data. First, *move-*

Table 7.8: Movement visualization classification from (Andrienko et al., 2017).

Category	Perspective	Example
Movement and transportation infrastructure	Understanding how the transportation infrastructure is used by travellers	Map showing the traffic density on the roads of a transportation network
Movement and behavior	Understanding the mobility choices of travellers as transportation infrastructure users	Visual tool showing the home-to-work daily mobility patterns, Topic visualization tool extracting the points of interest from social network content
Modeling and planning	Using movement data to build predictive models	Map using historical data to display the projected traffic perturbations caused by a future high-attendance event

Table 7.9: Further research directions suggested by previous surveys.

Survey	Research directions
(Andrienko and Andrienko, 2013)	• Improve the collaboration between visual analytics researchers and transportation experts
(Chen et al., 2015b)	• Build visualization tools that work with real-time data • Integrate heterogeneous data from different sources • Apply visual analytics on social transportation
(Zheng et al., 2016)	• Visualize data sparsity and uncertainty • Integrate heterogeneous data from different sources • Improve the scalability of visualization tools • Build visualization tools following a user-centered approach • Crowdsourcing to involve more stakeholders in data analysis • Study how the combination between automated analysis and visualization can be used to improve data analysis methods
(Andrienko et al., 2017)	• Improve the collaboration between visual analytics researchers and transportation experts for utility and usability purposes • Stay abreast of emerging trends such as social transportation • Integrate personal preferences into navigation systems • Improve the interactivity of simulations • Develop visualizations that foster collaborative engagement
(Sobral et al., 2019)	• Further study accessibility and commuting efficiency • Further exploit urban traffic conversations from social media • Further study 3D visualizations in the context of mobility • Research tools destined to help citizens in their commuting

ment and transportation infrastructure is concerned with understanding how the transportation infrastructure is used by travellers. Second, *movement and behavior* focuses on understanding the mobility choices of travellers as transportation infrastructure users. Finally, *modeling and planning* consists in using movement data to build predictive models. Their classification is detailed and illustrated by examples in Table 7.8.

(Sobral et al., 2019) surveyed works proposing visualizations of urban mobility data destined to expert users. More specifically, they categorized the surveyed works following the domain problem they address and the data source they use. The authors proposed an extension of the data source types classification from (Chen et al., 2015b).

Our literature review differentiates from the ones presented here in several ways. First, the process of selecting relevant works follows the widely accepted systematic literature review methodology described in (Kitchenham and Charters, 2007;

Kitchenham et al., 2015; Petersen et al., 2008), which allows achieving an objective and complete coverage. Second, the information extracted from the surveyed works covers visualization, interaction, data, domain, and end-user. These perspectives and their connections are necessary to build a complete guide for OGD portal developers. Lastly, our literature review distinguishes expert from lay citizen users, which is essential for the guide we aim at developing.

Scope and Research Question

The objective of this work is to study how information visualization supports the analysis of intra-city traffic data by collecting and analyzing the literature relevant in this regard. In order to frame the scope of the review, definitions of traffic and of visualization are provided.

Traffic is defined as the movements of human individuals in an area. In this review, a specific focus is put on the traffic within a city. This excludes several subdomains from the review scope such as vessel traffic (e.g. (Willems et al., 2009)), air traffic, and movements considered on a scale larger the city such as migration flows (e.g. (Boyandin et al., 2011)). Following the definition of Andrienko and Andrienko (2008), we consider traffic as the movements of a collection of individuals. Regarding **visualization**, two subfields are traditionally distinguished in the literature, namely scientific visualization and information visualization (Keim, 2010; Munzner, 2014). *Scientific visualization* consists in visualizing three-dimensional real-world entities and phenomena such as molecules and particle movement, and is therefore used when understanding shape is an important task. *Information visualization* refers to the representation of abstract and often high-dimensional data without explicit spatial reference, thus giving the designer freedom in how the space is used in the visual encoding. Traffic data is often visualized using geographic visualizations, which may appear as an ambiguous case as spatial coordinates are involved (Rhyne, 2003). However, according to Munzner (2014), the geometry can be viewed as a “backdrop against which additional information is overlaid.” Therefore, traffic visualization falls within information visualization (Keim, 2010). Recently, visualizations have been increasingly associated with automated data analysis techniques in a field defined as *visual analytics* (Keim, 2010), which is considered as a third subfield of visualization by some authors (Rhyne, 2008). However, data analysis techniques are out of the scope of this review, which focuses on visualization and on how it can support users in their tasks. Therefore, visual analytics works involving information visualization will be included in the review scope without considering the data analysis techniques they implement. Some authors (Lengler and Eppler, 2007) also differentiate data visualization (i.e. the use of all-purpose visualizations such as pie charts and line charts) and propose a more restrictive definition of information visualization (i.e. interactive representations that amplify cognition). In this review, we rely on the broader definition of information visualization from (Keim, 2010; Munzner, 2014), and therefore use information visualization and data visualization as equivalent concepts.

Research Question Refinement and Classification Scheme

The research question of this review was refined into six more specific research questions (SRQ). This refinement was guided by Munzner's What-Why-How framework (Munzner, 2014), which formalizes visualization into three components. First, the *What* covers the data used in the visualization, which we characterize in several ways (SRQ 2). Then, the *Why* regards the problem the visualization was designed to answer, which we considered by taking an interest in the domain of traffic that is addressed (SRQ 5). The third component of Munzner's framework is the *How*, which covers the visualization techniques and the interactions. We address the visualization techniques (SRQ 3) and the interaction (SRQ 4) as two distinct SRQ. We add a fourth component, the *Who*, which relates to the end-users of the visualization. We cover this dimension by considering who are the target end-users (SRQ 1), and whether they were involved in a user-based evaluation (SRQ 6). Figure 7.6 illustrates the arrangement of the four components, and the six resulting SRQ, as well as the logical connections between them, as described in Munzner's framework.

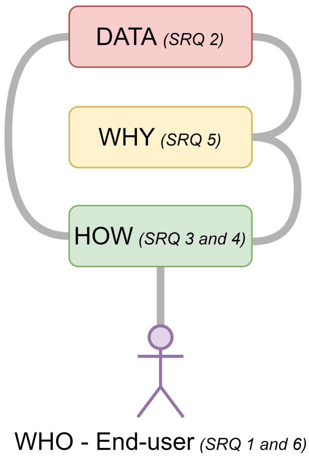


Figure 7.6: Arrangement of the six SRQs, adapted from Munzner's framework (Munzner, 2014).

Below, we detail how we extracted information from the surveyed articles for each of the six SRQ. This is summarized in the classification scheme shown in Table 7.10.

SRQ1: To which end-users are the visualizations destined? Two groups of end-users are considered, namely *Experts* and *Lay citizens*. The users considered as experts are those who have prior knowledge on mobility-related issues. Examples include, among others, researchers working in the field and city authorities. They interact with the visualizations in a professional context. On the other hand, lay citizens denote the users who do not have any particular knowledge of mobility-related issues, although they might be interested in them. Unlike experts, they encounter traffic data visualizations in a non-professional context.

Table 7.10: Classification scheme covering target end-users, data, visualization, interaction, domain, and user evaluation.

#	SRQ	Information	Categorization
1	End-user	Target	Lay citizens – Experts
2	Data	Dimension	Point – Line – Area
		Availability	Static – Dynamic
		Realness	True – Simulated
		Type	Nominal – Ordinal – Interval – Ratio
		Source	Citizens – Existing data – Internet of Things – Simulated
3	Visualiz.	Technique	Line chart – Bar chart – Heatmap – Parallel coordinates plot – Histogram – ...
		Map type	Dot map – Symbol map – Graduated symbol map – Network map – Ordered network map – Flow map – Colored area map – Ordered colored map – Choropleth map
		Architecture	1T – nT – 2D – 2D+1T – 2D+nT – 3D – 3D+1T – 3D+nT – 2D+3D – 2D+3D+1T – 2D+3D+nT
		Time visualiz.	Non-geospatial techniques – 3D – Animation – Time-flattening – Symbol on graduated symbol map – None
4	Interaction	ISM compliance	Yes – No
5	Domain	Domain	Mobility patterns – Congestion – Accidents – ...
6	User study	Conduct	Yes (number of participants) – No

SRQ2: What are the characteristics of the visualized datasets? The aim of this question is to study the features of the data from which a visual representation is generated. In particular, five characteristics of data are of interest:

- **Authenticity**: data can either be real or simulated. Real data comes from real world events and is labeled as *True*. Simulated data is mock data and is labeled as *Simulated*.
- **Source**: the source is the provider of the data. It can be *Existing data* such as mobile phone operator records or open data. Data can also come from *Citizens* via questionnaires or posts on social media for example. Another possibility is data collected using *Internet of Things* technologies such as cameras and sensors. The last possibility regards generated mock data, for which the source is labeled as *Simulated*. A clarification must be given for social media data. It is stored in the social media provider database, but has still *Citizens* as source because it is data provided by citizens on the platform, with an express will to do so. The source for phone operator data is *Existing data* because the data consists of activity records and is thus not provided explicitly as such by the operator's clients.
- **Availability**: traffic data is dynamic by nature because traffic situations evolve through time. A visualization that updates itself in response to these changes uses *Dynamic* data. On the contrary, historical data regards an elapsed timespan, and is therefore not subject to changes anymore. Such data is labeled as *Static*.
- **Dimension**: traffic-related data describes in-city situations and is thus often geospatial. The dimension of data refers to the kind of geospatial object to which the data relates. Maceachren (1979) distinguishes three geospatial objects, namely the *Point* which refers to a specific location in space, the *Line* which denotes connectivity, and the *Area* which represents a finite area

on a map. This characteristic of data is only relevant to consider when the visualization technique used is a geospatial map.

- **Type**: the data type refers to the scale on which the data is measured. Stevens (1946) lists four types of measurement scales: *Nominal*, *Ordinal*, *Interval*, and *Ratio*. The type of scale to which data belongs indicates which mathematical operations are permitted and influences the visualization techniques and visual channels used (Munzner, 2014; Harrower and Brewer, 2003).

Some articles mention the road infrastructure as a data source. However, in this survey, such data is not included in the data sources but is rather viewed as an overlay on which data is represented.

SRQ3: Which visualization techniques are used? The goal of this research question is to understand which visualization techniques are used in the surveyed papers. Well-known visualization techniques include, among others, the *Line chart*, the *Bar chart*, the *Heatmap* (which is a term originating from a work to represent financial information in the industry, and which is distinguished here from the geospatial heatmap frequently named so in general public media), and the *Geospatial map*. A comprehensive list of visualization techniques can be found online (Ribecca, 2019). It was used as classification baseline along with (Heer et al., 2010). It can happen that new visualizations are created by combining several existing techniques (e.g. a pie chart with line charts drawn on the arcs to give a temporal information on the categories). In such cases, each of the existing technique composing the visualization is counted once.

As mentioned earlier, traffic-related data is often geospatial. Thus, the geospatial map technique was refined using the map type classification proposed by Unwin (1981). He presents 12 map types determined by the dimension and the measurement scale of the represented data. Point data measured on a nominal (resp. ordinal, interval/ratio) scale is represented on a *Dot map* (resp. *Symbol map*, *Graduated symbol map*). Line data measured on a nominal (resp. ordinal, interval/ratio) scale is represented on a *Network* map (resp. *Ordered network map*, *Flow map*). Area data measured on a nominal (resp. ordinal, interval/ratio) scale is represented on a *Colored area map* (resp. *Ordered colored map*, *Choropleth map*). In accordance with the definition of the choropleth map, which is to rely on a predefined spatial partitioning, choropleth maps are not restricted to administrative limits. Maps colored following a predefined grid scheme (e.g. with square or hexagon shaped cells) fall within choropleth maps as well. The three remaining map types represent volume data. These map types were not considered in this review as visualizations of spatial properties in the context of traffic are either point-based, line-based, or area-based (Chen et al., 2015b; Zheng et al., 2016).

The surveyed works were also characterized by the architecture of visualization techniques they use, determined by the set of techniques integrated to constitute the proposed visualization tool. Tools can consist of one non-geospatial technique (*1T*), of more than one non-geospatial technique (*nT*), of only 2D maps (*2D*), of 2D maps with one other non-geospatial technique (*2D+1T*), of 2D maps with several other non-geospatial techniques (*2D+nT*), of only 3D maps (*3D*), of 3D maps with one other non-geospatial technique (*3D+1T*), of 3D maps with several other non-geospatial techniques (*3D+nT*), of 2D maps and 3D maps (*2D+3D*), of 2D maps and 3D maps with one other non-geospatial technique (*2D+3D+1T*), or of 2D maps and 3D maps with several other non-geospatial techniques (*2D+3D+nT*).

Finally, since the visual representation of time with spatial data is an important challenge for the field, we were interested in the existing approaches to represent space and time. We have listed five approaches. First, in order to represent the temporal dimension on a map, a dimension can be added. The result is a *3D visualization* where the spatial components of data are represented on the x and y axes, as a classic 2D map, and the temporal dimension is represented on the z axis. In the literature, this is referred to as the space-time cube (STC) model, which was first presented in 1970 by Hägerstrand (1970), who stressed the importance of analyzing human activities from a space-time point of view, and represented individual trajectories as polylines in a cube. However, the space-time cube visualization shows its limits when the number of trajectories to represent is too large (Andrienko and Andrienko, 2011; Demšar and Virrantaus, 2010). Several previous works addressed the issues related to the space-time cube by proposing solutions for e.g. viewpoint finding (Itoh et al., 2017; Li et al., 2017) and supporting immersive exploration of the STC (Wagner Filho et al., 2019). Others have represented spatio-temporal in a way that is based on the STC but aggregates trajectories to address the visual clutter issue. One technique for visually representing aggregated trajectories in the STC is stacking layers in a wall map fashion, where each layer gives average values (e.g. travel speed) for a set of trajectories (Cheng et al., 2010; Tominski et al., 2012; Andrienko et al., 2012a; Cheng et al., 2013; Romano and Jiang, 2017). Other techniques are isosurfaces, which consist in representing in the STC surfaces such that every point on the isosurface has a common value (Demšar and Virrantaus, 2010; Cheng et al., 2013), and density volume (Demšar and Virrantaus, 2010), which consists in coloring a volume according to the traffic density. The second approach is to combine maps with other *non-geospatial visualization techniques* able to represent the temporal dimension such as the line chart, the histogram, or the heatmap calendar view. The third approach performs *animation* of a map to display changes in time. The fourth approach consists in relying on time flattening to represent time on 2D trajectories. Perin et al. (2017) conducted an experimental study comparing different ways to encode speed and time (i.e. size, color value, and segment length) on 2D trajectories and concluded that using segment length is the best approach for encoding time on 2D trajectories. This method for representing time is named *time-flattening*. The fifth approach is somewhat similar to the combination between geospatial and non-geospatial techniques, but it relies on the *graduated symbol map* technique specifically. The symbol used on the graduated symbol map can be a visualization technique in itself able to display temporal data (e.g. line chart). For each work, we noted the methods used to represent time with spatial data. For the works not using any geospatial visualization technique, and thus not representing spatial data, the *not applicable* label was attributed. Indeed, the focus is on how the surveyed works represent both space and time visually. Other works do propose geospatial visualization but do not represent time visually and were given the label *none*. For example, these works might propose interactive time filters to allow discovering temporal patterns, but there is not any visual encoding of temporal information.

SRQ4: How is interactivity supported by the used visualization techniques? Interaction in the context of information visualization allows end-users to manipulate a visual representation according to their needs. Shneiderman (1996) proposed a taxonomy including seven high-level interaction tasks, namely *Overview*, *Zoom*, *Filter*, *Details-on-demand*, *Relate*, *History*, and *Extract*. He also formulates the Information Seeking Mantra (ISM) "Overview first, zoom and filter, then details-on-demand" as guideline for interaction design. This mantra indicates that a visual interface should at first provide the user with an overview of the data at hand, then offer filtering and zooming features to allow focusing on a subset of interest, and finally give specific details on this subset. The Information Seeking Mantra is a well-established guideline in the traffic data visualization field, and was used as a guide for interaction and visual design in numerous works (e.g. (Palomo et al., 2015; Zeng et al., 2016; Wongsuphasawat et al., 2009; Pu et al., 2013)). Another reason for selecting the Information Seeking Mantra instead of other classifications is to evaluate the interaction aspect on the visual tool as a whole rather than on every visualization technique separately. Indeed, in some cases, an article presents a visualization tool consisting of several integrated techniques where different visualizations present information at a different level of detail. Separately, it may happen that none of them is compliant with the mantra. Still, they may together constitute a tool respecting this good practice. Since this literature review focuses on visualization rather than interaction techniques, a high-level view of interaction is kept. The focus is put on checking in a binary way whether the surveyed papers comply with the Information Seeking Mantra.

SRQ5: To which traffic-related problems do the visualizations answer? This fifth SRQ addresses the question of why a visualization was built in the first place.

In traffic flow theory, and more specifically in simulation modeling, three levels are generally distinguished to represent traffic (Elefteriadou et al., 2014). The microscopic level focuses on individual vehicles and their behavior such as lane changing. The macroscopic level aggregates the activity of the individual vehicles and characterizes traffic in terms of flow rate (i.e. the rate at which individuals reach a given location in a given timespan) and density (e.g. the number of individuals present at a given location at a given time). The mesoscopic level is a hybrid of the microscopic and the macroscopic levels.

For SRQ 5, we were however more interested in the application domains rather than the level of representation, we therefore extracted this information instead. The domains were extracted without classification scheme beforehand. They were then grouped together into ten categories following the labels attached during the review of the articles. Connections exist between the identified domains. For example, accidents cause road congestion, which in turn increases travel times and creates pollution peaks at specific areas. It can thus occur that the line of work of a paper spans several domains. When such a case occurred, each relevant domain was incremented. Some articles propose a more general solution, that is not designed to address one single class of problems. In such cases, the domains were extracted from the case studies on which the authors demonstrated their contribution.

SRQ6: Are user studies systematically conducted on the proposed visualizations? User evaluations are crucial to determine whether a visual tool is suitable to the needs and desires of the end-users it is destined to (Hartson and Pyla, 2012). The label *Yes* is attributed to the articles that present a user study of any kind, from the informal interview with one end-user to the formal multi-user evaluation. The number of users involved, if known, is noted as well. A popular approach for validation in the field is the report of case studies conducted by the authors. However, only studies conducted with end-users fall within the scope of this SRQ. Also, some articles report end-user involvement in earlier stages, especially in defining the tasks. However, the focus is on the evaluation stage.

Search Terms

After defining the research question, the following step is to formulate it as a machine-understandable query in order to retrieve the relevant literature with digital libraries search engines. Petticrew and Roberts (2006) proposed the PICOC (Population, Intervention, Comparison, Outcomes, Context) framework as a way to structure a query. In this survey, only the Population and the Intervention are considered, as the search query is run on the title field of the articles. The population is the application area for visualization, that is, traffic. The synonyms considered for *traffic* are *mobility*, *travel*, *accessibility*, *transport*, *transportation*, *trip*, *trajectory*, and *movement*. The intervention is what is used to address the issues described in the population, that is, the visualization. Along with *visualization* and *geovisualization*, their spelling variants *visualisation* and *geovisualisation*, and the keywords *visual* and *geovisual* are considered as well. In order to further expand the coverage, *explore* and *exploration* were added. The keywords were organized using Boolean operators, applying the PICOC framework. The resulting search string was applied alike for the selected digital libraries and is as follows:

```
(Traffic OR Mobility OR Travel OR Accessibility OR Transport OR
Transportation OR Trip OR Trajectory OR Movement)
AND
(Visual OR Visualization OR Visualisation OR Geovisual OR
Geovisualization OR Geovisualisation OR Explore OR Exploration)
```

Selected Digital Libraries

In order to gather as many of the relevant studies as possible, the aforedefined search query was applied to four prominent digital libraries, namely ACM Digital Library (ACM DL), IEEEXplore, ScienceDirect, and Wiley Online Library (WOL). This choice was driven by two reasons. First, the selected libraries, especially ACM DL and IEEEXplore, are very popular in computing-related topics (Kitchenham et al., 2015). Second, the selection covers both conference and journal papers.

Inclusion and Exclusion Criteria

Inclusion and exclusion criteria are the filters used to determine whether a work is relevant for the research question. A paper is considered relevant if it satisfies the inclusion criteria and none of the exclusion criteria. Given the wide scope of the research question, only one broad inclusion criterion is defined. Relevant research presents information visualization tools supporting intra-city traffic analysis.

The exclusion criteria defined for the survey and their rationale are as follows:

(i) **Articles not written in English**.

(ii) **Duplicated articles**: some papers are returned by more than one of the search engine, thus leaving duplicates in the set of relevant papers. The concerned papers are considered only once, and the duplicates are removed. When two versions of the same contribution are published, only the most recent is considered.

(iii) **Articles published before 2008**: a time frame of 12 years is considered representative of the body of research in the field. Publications before this date are rarer and were probably superseded by more recent advances.

(iv) **Secondary studies**: a survey consists in a review of primary studies (Kitchenham and Charters, 2007). Secondary studies (i.e. survey contributions) gathered through the article search were discussed in the “Need for a Review” section.

(v) **Articles published in poster, challenge, or demo tracks**: these articles are very short and usually present research that is at a preliminary stage, and therefore do not provide the information needed for applying the classification scheme correctly.

(vi) **Articles that do not provide any figure representing the proposed visualizations**: the analysis of visualization techniques is part of our classification scheme. Having no figure at hand would thus hinder the correct analysis.

(vii) **Articles proposing visualizations not directly destined to any end-user**: some articles present visualizations of traffic data that are not destined to be used afterwards by any end-user. It is the case when the authors use information visualization as a means of sharing their findings on a research question unrelated to visualization. These were excluded, as this survey focuses on visualizations destined to end-users. Some articles discuss visualization techniques that can be applied to traffic data, but do not provide an implemented system actually destined to be used. These were excluded for the same reason.

(viii) **Traffic beyond the city scale**: articles discussing traffic that goes beyond the city scale such as air, maritime, or train traffic were excluded.

Extraction of Relevant Works

The search yielded 3,555 papers. However, a correction had to be applied for the results returned by the ACM DL, ScienceDirect, and WOL. For these libraries, the inclusion of inflected forms of the search keywords was too permissive. For example, *mobile* and *access* were accepted as inflections of *mobility* and *accessibility* respectively. Such inflected forms modify the semantics of the search string and thus cause

Table 7.11: Number of relevant studies per digital library (snowball analysis not included).

Digital library	Articles returned	Relevant articles	% Relevant articles
ACM DL	294	18	6.1%
IEEEXplore	867	90	10.4%
ScienceDirect	783	15	1.9%
WOL	370	5	1.4%
Total	**2,314**	**128**	**5.5%**

the search to return a large number of articles not actually matching the keywords and relating to other fields. The correction consisted in removing the concerned articles by checking their title. As a result, 1,214 articles were removed. For each of the digital libraries, some duplicates were returned. The 27 concerned articles were removed as well. Therefore, the search returned 2,314 unique articles congruent with the search string, across the four digital libraries.

The relevance of each article to the review was assessed by reading its title and abstract. Table 7.11 shows the number of articles yielded by the initial search for each digital library, as well as the amount of relevant works collected. In total, 128 primary studies constitute the body of relevant research yielded through the initial search.

In order to collect studies outside the searched digital libraries, a backwards snowball analysis (BSA) was performed on the 128 articles. Combining the search on digital libraries with snowball analysis is a recommended practice when conducting a survey, as it leads to better results (Mourão et al., 2020). The bibliography of the articles underwent the same search query as the digital libraries. Also, as the goal of this survey is to provide a representative vision of the field, the articles that appeared in 5 bibliographies or more were considered, regardless of whether their title is congruent with the keywords. This allowed some mitigation of the title field limitation by including several additional works. The process yielded 70 distinct relevant papers, most of which (52) were already included in the initial pool of articles. The 18 works that were not captured by the initial search were added to the review body, thus amounting to 146 works. A second BSA on these 18 articles yielded no additional relevant work. Appendix E lists the 146 relevant articles returned through the search on the digital libraries and the BSA.

Categorization Process

The authors of the surveyed papers were not contacted for the categorization process. The information relating to the six SRQ was extracted from the papers by two researchers. Each of them read the papers independently and the results were then confronted for each paper. Disagreements were solved by discussing until reaching a consensus. Although involving only two researchers in the categorization is a limitation, it was mitigated by performing retest (i.e. second reading and categorization) on a large part of the surveyed articles, thus ensuring consistency in the categorization.

For each article, the categorization was guided by the categories defined for the SRQ, and information was collected by looking for explicit mentions in the manuscript. Information was also collected from the figures for SRQ 3 and SRQ 4 (e.g. a filtering widget on the interface screenshots indicates that the *zoom and filter* part of the mantra is satisfied). When a working URL pointing to the proposed system was provided by the authors of the article, it was checked in order to confirm the information collected from the manuscript. The acknowledgment part was analyzed for SRQ 2, as the data provider is acknowledged by the authors in some cases.

Coverage Assessment

In order to assess how complete a search strategy is, the set of articles yielded by the search has to be compared with another set of articles from the field. There are several ways to determine the latter (Kitchenham et al., 2015), namely a restricted automated search, the knowledge of the researchers conducting the review, previous literature reviews, and constructing a quasi-gold standard. Given the number of previous literature reviews available, the chosen approach was to rely on the five literature reviews discussed in this section.

The bibliographies of these literature reviews (Andrienko and Andrienko, 2013; Chen et al., 2015b; Zheng et al., 2016; Andrienko et al., 2017; Sobral et al., 2019) were screened and the relevance of each paper to the survey was checked. In total, 80 relevant articles were identified, composing what we refer to as the *known set*. Then, from the known set, the recall of the search strategy could be computed by checking how many of these 80 articles were returned by the search strategy. 50 of them were retrieved, resulting in a recall of 63%. Another recall was computed by weighting the articles from the known set according to the number of related reviews bibliographies they appear in. For instance, the article (Tominski et al., 2012) is cited by (Andrienko and Andrienko, 2013; Chen et al., 2015b; Zheng et al., 2016; Andrienko et al., 2017) and is therefore given a weight of 4. The article (Yin et al., 2015) is given a weight of 1 because it is cited only in (Sobral et al., 2019). The recall computed with the weights is 77%. These results show that some articles are not captured by the devised search strategy. Nonetheless, the most prominent articles from the field are successfully captured by the search strategy, as shown by the much higher value of the weighted recall. Since this review is a qualitative survey (thus, having a less critical completeness requirement (Kitchenham et al., 2015)) that aims at giving a representative vision of the field, we consider that a 77% weighted recall is acceptable.

Among the 30 articles from the known set that were not captured, 5 are congruent with the search terms but are not indexed by the surveyed digital libraries, and therefore could not have been captured by the initial search. The other 25 articles were not captured because their title does not match the search terms. This suggests that searching on the title field only was the most limiting factor for the coverage.

Searching on the abstract field instead would have partially mitigated this issue and returned 16 of the 25 concerned articles. However, expanding the search to the abstract field was not feasible, as the initial search would have returned over 17,000 results, for the IEEEXplore search engine only.

Reporting the Review

In the next section, we report on the findings drawn from our review. We successively address the six SRQ defined earlier and provide visual representations of our findings for better readability. We also discuss research trends extracted by analyzing the connections between the SRQ as well as research gaps. Appendix E provides the categorization information extracted for each of the surveyed articles. A supplementary spreadsheet[6] also provides the necessary methodological details (e.g. decision for each excluded article, composition of the known set) as well as the categorization information in a more convenient format.

7.4.2 Visualization Guide

The surveyed works mainly propose expert systems allowing users to work with historical data provided by governmental authorities, public transport services, or phone operators. In most cases, one data source is used. The visualization techniques used are diversified, but the geospatial visualization is obviously prominent. It is often combined with other popular charts such as the line chart, the histogram, and the heatmap calendar view. Most of the reviewed systems comply with the Information Seeking Mantra, which seems to be a fairly established guideline in the field. The domains tackled most often include mobility patterns and congestion. Most systems did not undergo a user study, though it should be noted that illustration of the system through case studies by the authors is a popular practice. These overall trends lead to reiterate recommendations that were raised by previous surveys, such as the need for systems that integrate several data sources (Zheng et al., 2016; Chen et al., 2015b) and the need to work with real-time data (Chen et al., 2015b).

These findings are detailed for each SRQ successively in the following paragraphs. Afterward, additional findings related to the connections between SRQ are presented. The connections discussed are the most frequent visualization approaches (i.e. techniques and architectures) for a given domain, a given data source, and a given target audience.

Target end-users (SRQ 1)

In total, 115 of the surveyed articles propose visualizations exclusively destined to experts. For lay citizens, this number (10) is approximately 11 times smaller. 15 articles target both lay citizens and experts. The 6 remaining articles do not specify whether the end-users are experts or lay citizens (Figure 7.7).

Figure 7.8 shows an example of tree visualization from (Zeng et al., 2014) destined to experts. It represents multimodal trips originating from the same location and

[6] https://doi.org/10.5281/zenodo.4287513

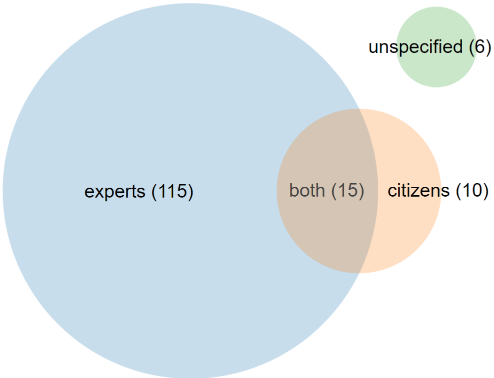


Figure 7.7: Target end-users in the surveyed works (SRQ 1)).

details the distribution of time between transportation modes and waiting. A circular stacked histogram allows comparing this distribution according to the time of day. An example of geospatial visualization designed for lay citizens from (Nagel et al., 2017) is shown in Figure 7.9. It represents the animated flow of bikes in a city.

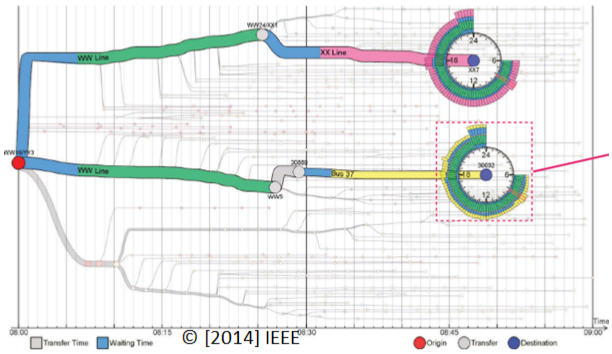


Figure 7.8: Tree visualization representing the distribution of time between transportation modes and waiting of multimodal trips originating from a given location. A circular stacked histogram allows comparing this distribution according to the time of day (reproduced from (Zeng et al., 2014)).

Data (SRQ 2)

As explained in Section 7.4.1, the data used in the surveyed visualizations was considered under five aspects. In this section, the data availability, authenticity, and source are successively discussed. The data type and dimension were captured in order to refine the classification of geospatial visualizations following (Unwin, 1981), and are therefore not addressed as such.

A first striking observation is the low amount of papers using dynamic data. Although not relevant in every work domain, dynamic traffic data remains critical

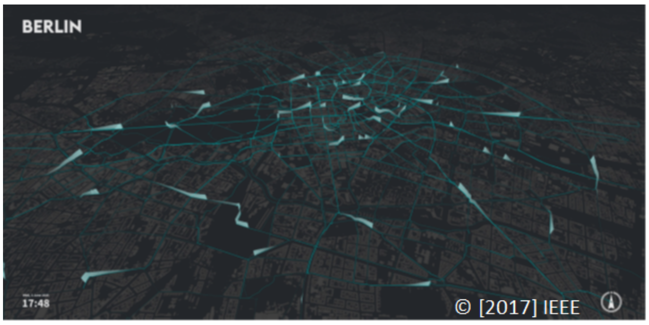


Figure 7.9: Map showing the animated flow of bikes in a city (reproduced from (Nagel et al., 2017)).

for use cases such as congestion, route recommendation, and accident analysis. Still, 130 of the 146 (89%) reviewed papers use only static data. The development of more systems using real-time traffic data was stated as a recommendation for the field in (Chen et al., 2015b). However, there is no significant difference in the proportion of articles using dynamic data published per year.

With regard to the authenticity of the data, it can be observed that a large majority of the articles use true data (136 papers, 7 of which using also simulated data). This suggests that real-world data is relatively easy to obtain for research purposes. Following our classification scheme, true data has three possible sources, namely citizens, IoT, and existing data. Data from citizens was further refined into *Transparent* for cases where citizens were involved in the data collection process (e.g. volunteered tracking) and *Non transparent* data for other cases (e.g. data collected from their social media posts). Data from the Internet of Things technologies was collected mainly from cameras and other sensors. As for the existing data sources, they are usually provided by the authorities, by a company active in the transportation sector, or by another private company such as a phone operator. Figure 7.10 displays the data sources along with their use frequency in the surveyed articles. The total frequency (176) exceeds the number of articles because some make use of several data sources. Each data source was counted once in this case.

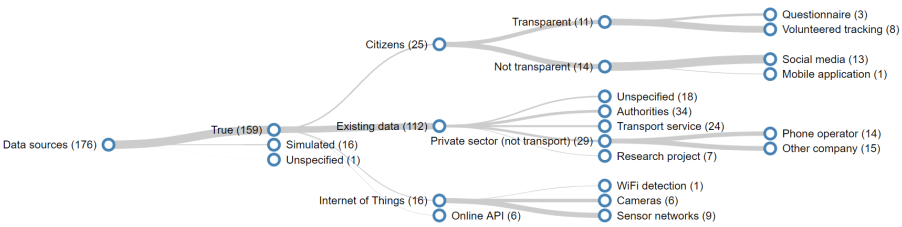


Figure 7.10: Tree showing the data authenticity and sources for the surveyed articles. The number of articles using a given data source is noted in parenthesis next to the corresponding node (SRQ 2).

Figure 7.10 shows that eight main true data sources are used. **Authorities** (34) possess rich data relating to the territory they govern. Recently, they have become aware of the added-value their data can bring. As a result, many open government data (Veljković et al., 2014) initiatives have emerged. This is reflected in the findings of this review. Among the 6 articles collected from 2020, 2 use open data (Feng et al., 2020; Tsung et al., 2020). Another recurring example of data provided by the authorities is taxi data (Ferreira et al., 2013; Poco et al., 2015; Krueger et al., 2016; Liu et al., 2018; Dai et al., 2019; Al-Dohuki et al., 2021). **Transportation services** (24) own the richest data on the use of their services. A recurring example in literature is the Mass Rapid Transit in Singapore which collects data through their tap in and tap out system (e.g. (Zeng et al., 2013; Yu et al., 2015; Zeng et al., 2016)). **Phone operators** (15) have fine-grained information on the location of their users. In the surveyed papers, their datasets span several months, which can prove useful to, e.g., study where people travel over an extended time lapse. **Social media** (13) and **online APIs** (6) are data sources accessible online at a reduced cost. These are prominent sources for obtaining real-time data. **Sensor networks** (9) are deployable at a reasonable cost provided that they span a restricted area. There is some leeway regarding the data that can be collected and its granularity. **Volunteered tracking** (8) involves citizens in the data collection process by gathering information on their mobility activities (e.g. places visited during the day). Finally, several articles reported using data collected in the context of another **research project** (7).

Visualization Techniques (SRQ 3)

Geospatial maps are the most used technique in traffic data visualization. This makes sense since this data is inherently geographical. In total, 136 out of the 146 surveyed articles make use of geospatial visualization. 2D visualization is more popular than its 3D counterpart, with respectively 126 and 22 uses in the surveyed papers (12 articles use 2D and 3D geospatial visualization simultaneously). Both 2D and 3D have their pros and cons. On the one hand, 3D geospatial visualizations allow displaying the spatial and temporal components of data on a unique representation, but they are usually displayed on a 2D screen and are as such difficult to read and less effective for users to carry their tasks (Andre and Wickens, 1995). On the other hand, 2D geospatial visualizations often have to be combined with other visualization techniques to represent temporal aspects. Combining visualizations induces no readability problem but may hinder the overview.

We observed that maps are more frequently used with ratio data because this type of data is recurrent in many mobility-related issues (e.g. how many vehicles are there at a given location, how many people moved from an area to another). Nominal data comes in second place, as many maps only represent the spatial dimensions of data items and rely on additional techniques for other dimensions. Ordinal and interval data are scarcely used. It illustrates two distinct trends in research: representing as many attributes of data items as possible on a map, or representing only the spatial dimensions and relying on other techniques. Another interesting observation is that the *area* data dimension is rarely used. Table 7.12

Table 7.12: Frequency of map types in the surveyed articles.

Data type	Point data	Line data	Area data
Nominal	Dot map (34)	Network map (26)	Colored area map (6)
Ordinal	Symbol map (1)	Ordered network map (11)	Ordered colored map (0)
Interval or ratio	Graduated symbol map (80)	Flow map (67)	Choropleth map (18)

shows the frequency of map types in the surveyed articles. The most frequently used geospatial visualization is the graduated symbol map. Its most frequent form is the density map (e.g. (Puertas et al., 2013; Cristie et al., 2015; Zhang and Wang, 2017; Pei et al., 2018; Dai et al., 2019; Wang et al., 2019; Feng et al., 2020; Zhao et al., 2020)), but graduated symbol maps have also been used to represent symbols of varying size (e.g. (Guillén et al., 2011; Di Lorenzo et al., 2013; Bast et al., 2014; Lu et al., 2015; Shan et al., 2018)) or opacity (e.g. (Krüger et al., 2014; You et al., 2019; Tsung et al., 2020)). Some articles also use full-fledged visualization techniques as symbols. Graduated symbols maps have been used with heatmaps (Pu et al., 2013; Liu et al., 2013; Andrienko and Andrienko, 2008), line charts (Wood et al., 2011), bar charts (Montero et al., 2017), pie charts (Simmons et al., 2015), rose charts (Bak et al., 2012, 2015; Huang et al., 2015), area charts (Andrienko et al., 2012b), and concentric circles (Nagel et al., 2014), among others.

Figure 7.11 shows the visualization techniques encountered throughout the review on a node-link diagram. The size of the nodes represents the number of articles which resorted to the corresponding technique and the thickness of the links depicts the number of articles that used the connected techniques together. The techniques used in 3 articles or less are grouped together under the “other technique” label. The previously observed predominance of the 2D-geospatial visualization is startling in the display. The thickness of the links illustrates that articles often use more than one visualization technique.

Regarding architecture, most of the surveyed works have a visualization technique architecture relying on 2D maps. The most frequent is 2D+nT, which is used in 59 out of the 146 surveyed articles. It is followed by 2D (37), 2D+1T (18), 3D (6), 1T (5), 2D+3D+1T (5), 2D+3D+nT (5), nT (5), 2D+3D (2), 3D+1T(2), and 3D+nT (2). The visualization techniques most frequently used in 2D+1T and 2D+nT architectures are the heatmap, often used as a calendar view (39), the histogram (37), the line chart (35), the scatterplot (19), the bar chart (18), and the parallel coordinates plot (14). It is interesting to note that whereas 2D maps are more often used along with other non-geospatial techniques, the most frequent architecture involving 3D maps (excluding those including 2D as well) does not include other non-geospatial techniques. This can be explained by the third dimension making it possible to represent another dimension besides space, whereas another visualization would be needed to represent the same information with a 2D map. Figure 7.12 shows an example of 3D-geospatial visualization from (Cheng et al., 2013). It represents the variation

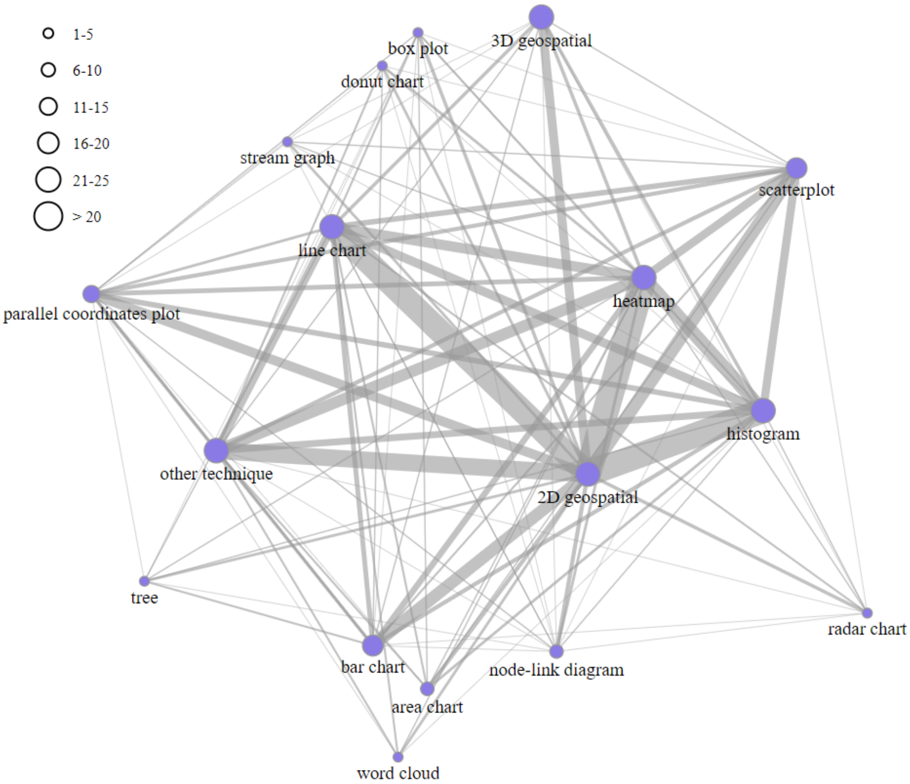


Figure 7.11: Node-link diagram showing the connections between the visualization techniques. Nodes depict techniques and have a size representing the number of papers using them. Links depict connections between techniques and have a thickness representing the number of papers using both the connected techniques together (SRQ 3).

of congestion through time by stacking the values of each time bin on the z axis. Congestion is measured by the time needed to travel 1 kilometer. Figure 7.13 shows a choropleth map with a line chart from (Senaratne et al., 2017). It can be seen that the map represents only the data of a limited time span. The line chart gives the whole temporal view.

The most frequent method to represent time visually is the use of non-geospatial techniques (NGT), applied in 82 of the surveyed articles. This was expected, as the most frequent architectures combine a 2D map with non-geospatial techniques. Animation (A) is supported by 19 articles and is most frequently used with 2D maps. Animation is the preferred method among articles using a 2D architecture. The third most popular method for representing time visually is using 3D. More than half of the surveyed works involving 3D in their visualization architecture use this approach. Symbols on a graduated symbol map (SGSM) are used in 11 of the surveyed articles to represent time, mainly in those relying on a 2D only architecture.

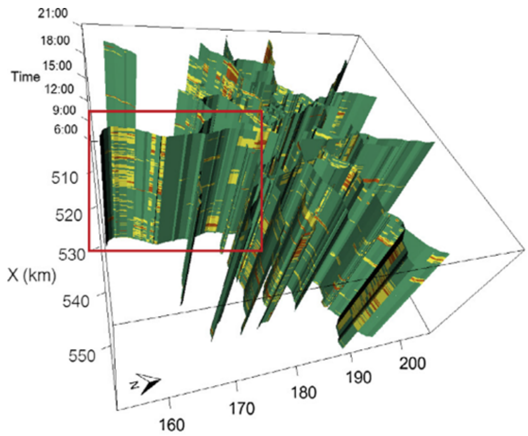


Figure 7.12: 3D-geospatial visualization representing the variation of congestion through time by stacking the values of each time bin on the z axis (reproduced from (Cheng et al., 2013)). Congestion is measured by the time needed to travel 1 kilometer.

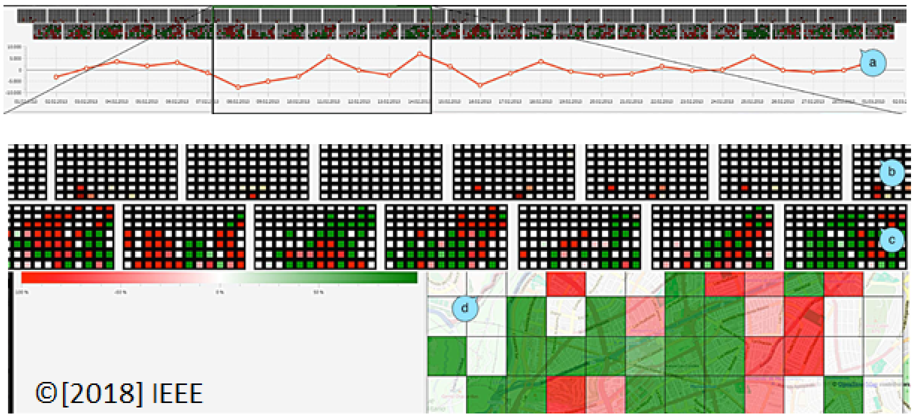


Figure 7.13: Choropleth map showing data for a limited time span with a line chart giving the whole temporal view (reproduced from (Senaratne et al., 2017)).

Time flattening (TF) was used in only three articles. Pu et al. (2011) use size and represents information in the form of an area chart displayed alongside the roads on a flow map. In (Baskaran et al., 2017), time is mapped to a color spectrum and portions of trajectories are colored according to the time of the day they occurred (e.g. red corresponds to 12am). In (Nagel et al., 2017), bike trajectories are represented on a 2D map using a color value and size encoding. 27 of the surveyed articles use two approaches simultaneously, including most of those relying on a 2D+3D+1T or 2D+3D+nT architecture. Among the remaining works, 34 do not represent time visually, most of them not using any visualization technique besides the 2D map. Lastly, 10 articles do not use geospatial visualization techniques, and therefore were

Table 7.13: Use of time visual representation methods per visualization technique architecture.

Architecture	NGT	3D	A	SGSM	TF	none	NA
1T	0	0	0	0	0	0	5
nT	0	0	0	0	0	0	5
2D	0	0	7	5	2	24	0
2D+1T	14	0	2	2	0	4	0
2D+nT	55	0	6	3	1	4	0
3D	0	3	1	0	0	2	0
3D+1T	2	0	1	0	0	0	0
3D+nT	2	1	1	0	0	0	0
2D+3D	0	2	0	0	0	0	0
2D+3D+1T	5	5	0	0	0	0	0
2D+3D+nT	4	3	1	1	0	0	0
Total	**82**	**14**	**19**	**11**	**3**	**34**	**10**

given the *not applicable* (NA) label. Table 7.13 gives the number of uses of the visual time representation approaches, for each architecture.

Interaction (SRQ 4)

In total, 104 of the 146 surveyed articles are compliant with the Information Seeking Mantra "Overview first, zoom and filter, then details-on-demand" (Shneiderman, 1996) (Figure 7.14). Table 7.14 provides numbers for each target end-user category. Most of the articles are compliant with the mantra, which is an encouraging result. Indeed, the presence of interaction features on visualizations allows users to make a much richer use of it.

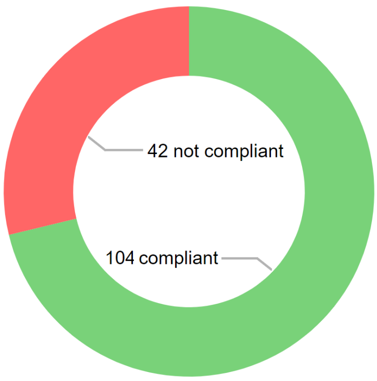


Figure 7.14: Compliance of the surveyed works to the Information Seeking Mantra (SRQ 4)).

Table 7.14: Number of articles compliant with the Information Seeking Mantra (Shneiderman, 1996) for each end-user category.

Target end-users	Compliant	Not compliant
Experts only	82	33
Lay citizens only	7	3
Both experts and lay citizens	12	3
Unspecified	3	3
Total	**104**	**42**

Domain (SRQ 5)

In total, 10 domains characterize the surveyed research (Figure 7.15). **Mobility patterns** (73) relate to the mobility behavior of the city inhabitants and visitors, with an origin/destination view of the trips. The articles address mobility patterns under several (non exclusive) perspectives, such as the routes taken to travel from an origin to a destination (Liu et al., 2011; Zheng et al., 2015; Liu et al., 2018; Andrienko and Andrienko, 2008), the identification of origin/destination pairs regardless of the routes (Ferreira et al., 2013; Zhang et al., 2015; Dash et al., 2015; Zheng et al., 2015; Jiang et al., 2015; Shamal et al., 2019), or the semantics of the origin and destination locations (Krüger et al., 2014; Chu et al., 2014; Krueger et al., 2017; Tang et al., 2018; Liu et al., 2019). **Congestion** (40) analysis studies questions such as the location, the magnitude, the frequency, and the reasons for occurrence of congestion events. **Microscopic movements** (13) relate to the movements of vehicles and people, regardless of the origin and destination of their trips. Examples include changing lanes on a road. **Public transportation use** (12) refers to understanding how people move with public transportation networks. **Accessibility/travel time** (12) relates to the reachability of a location, often expressed in terms of travel time. The **accidents** (10) domain refers to the analysis of traffic-related incidents such as collisions and of their impact. **Pollution** (6) covers the impact traffic has on the environment. In many cases, the impact studied relates to emissions, but other types of nuisance such as noise fall within the scope of pollution as well. **Anomaly detection** (4) refers to detecting individuals who have a mobility behavior significantly different from what is normally observed. For example, detecting pickpockets active in public transports (Zhao et al., 2020). **Route recommendation** (2) is a process taking into account various parameters and constraints to determine the optimal route between an origin and a destination. **Parking availability** (1) refers to the number of parking spots available to accommodate travelers.

Two lines of work are prominent in the surveyed articles, namely mobility patterns and congestion. With regard to mobility patterns, their popularity can be explained by the wide range of questions they allow answering. As for congestion, it is the mobility-related issue that incurs the highest financial costs, and is thus given a lot of attention. On the other hand, pollution, accessibility, and accidents appear less intensively studied. Figure 7.16 shows a geospatial visualization from (Yu et al., 2015) displaying identified mobility patterns originating from the *home* location.

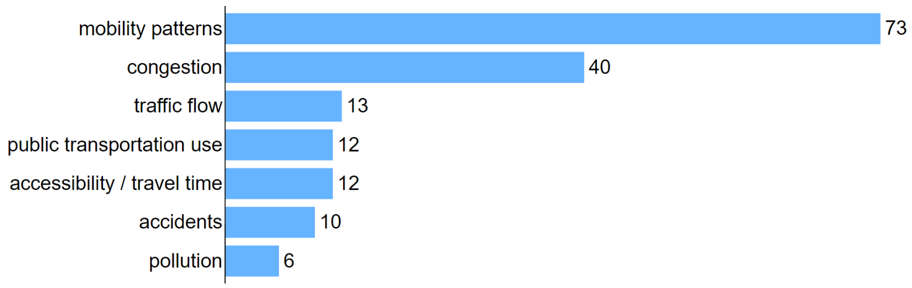


Figure 7.15: Domains studied by the surveyed works (SRQ 5)).

Figure 7.17 shows an example of map from (Kalamaras et al., 2017) displaying the congestion on a road network. A color code is used to represent three levels of congestion, going from *normal traffic* to *significantly altered traffic*.

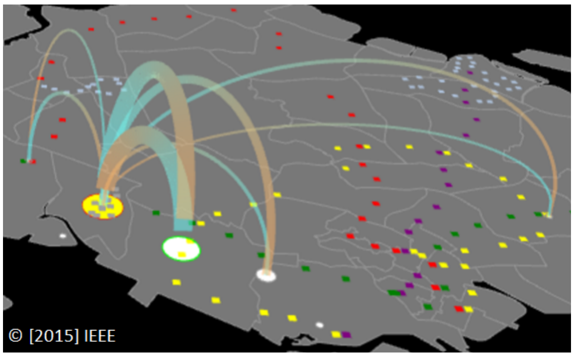


Figure 7.16: Geospatial visualization showing identified mobility patterns originating from the *home* location (reproduced from (Yu et al., 2015)).

Table 7.15 shows the domains addressed by the surveyed articles according to the target end-users. The aforementioned prominence of the mobility patterns and congestion domains concerns both end-user groups, but is less striking in the 25 articles including lay citizens in the target end-users.

User study (SRQ 6)

Only 48 of the 146 surveyed papers include a user study. Out of these 48 articles, 12 do not specify the number of participants of the evaluation, 23 involved between 1 and 10 participants, and 13 evaluated their contribution with more than 10 participants (Figure 7.18).

Which Visualizations for which Domain?

Regarding architecture (Table E.2), 2D is the most popular approach for congestion (16), and 2D+nT is the most frequent for mobility patterns (37) and public transporta-

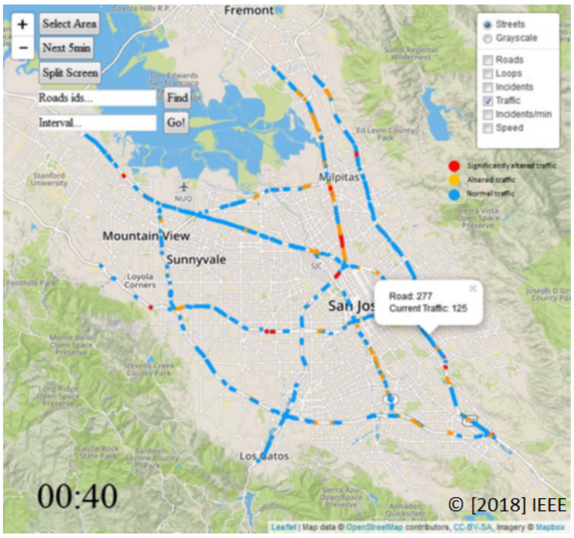


Figure 7.17: Map displaying the congestion on a road network. A color code is used to represent three levels of congestion, going from *normal traffic* to *significantly altered traffic* (reproduced from (Kalamaras et al., 2017)).

Table 7.15: Domains addressed by the surveyed articles according to target end-users.

Domain	Experts only	Lay citizens only	Both experts and lay citizens
Mobility patterns	**61**	**3**	**5**
Congestion	**33**	**2**	**4**
Microscopic movements	9	1	3
Public transportation use	7	1	3
Accessibility/travel time	7	**2**	2
Accidents	9	1	0
Pollution	5	0	1
Anomaly detection	3	0	1
Route recommendation	2	0	0
Parking availability	2	0	0

tion use (5). 2D and 2D+nT have a similar use frequency for microscopic movements (5 and 5) and accessibility/travel time (4 and 5). As for accidents, 2D+1T and 2D+nT are used 4 times each. Although few of the surveyed works analyze pollution, it was observed that 3D is as popular as 2D (2), and thus far more frequently used to study pollution than other domains, proportionally.

As for geospatial visualization techniques (Table E.3), area-based maps are rarely used, and point-based and line-based maps have a similar use frequency. However, there are some differences across domains. Point-based is the most popular for mobility patterns and accidents. Line-based is the most popular for congestion, accessibility/travel time, and anomaly detection. Both approaches have a similar

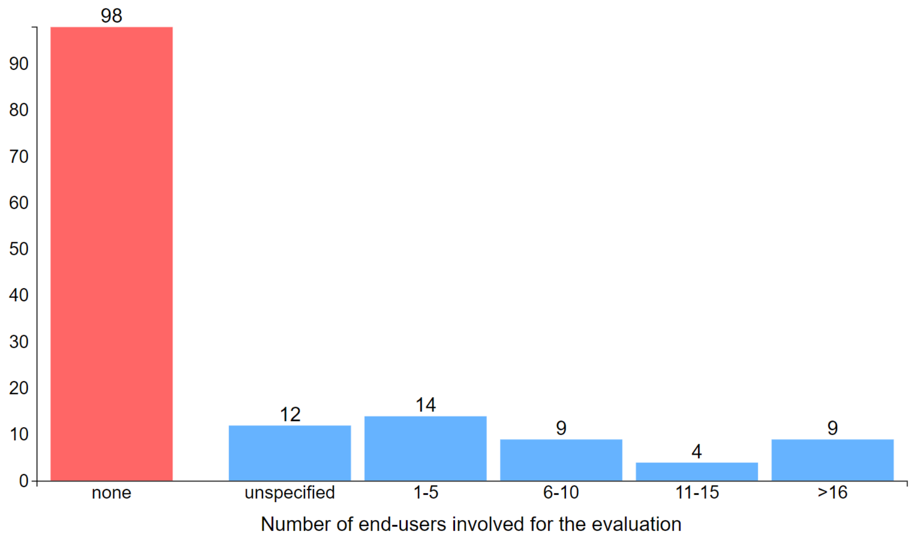


Figure 7.18: Conduct of user studies in the surveyed works (SRQ 6)).

frequency for microscopic movements, public transportation use, and pollution. For accessibility/travel time, area-based maps are as frequent as point-based maps. It is the domain for which area-based maps achieve the highest proportion. On the contrary, area-based maps were encountered only once for congestion. As for the precise map types, the most frequent across all domains are the 2D graduated symbol map and the 2D flow map. The totals of the three map subtypes might add to more than the frequency of the upper map type. For example, if an article uses a dot map and a graduated symbol map, each subtype would be incremented, whereas the count related to point-based maps would increment by only 1.

Finally, concerning non-geospatial techniques (Table E.4), the most frequently encountered in the surveyed articles are the heatmap and the line chart. We observed few significant differences across domains. Yet, we noted that node-link diagrams are used almost exclusively for mobility patterns and that the parallel coordinates plot is proportionally more frequently used for mobility patterns than other domains.

Which Visualizations for which Data?

Concerning the architecture (Table E.5), 2D+nT is the most frequent for data from authorities (16), transport services (10), phone operators (8), other private companies (8), and research projects (3). Thus, 2D+nT is the most prominent for every data source in the *Existing data* category. 2D+nT is also the most frequent architecture for data collected by Internet of Things technologies (7). As for data from citizens, 2D and 2D+nT have a similar frequency (8 and 7). Finally, 2D is the most used for simulated data (8). Simulated data is used in only 16 of the surveyed works, but still counts for half the occurrences of the 3D architecture. Proportionally, map-only architectures are much more frequent for simulated data.

Regarding geospatial visualizations (Table E.6), area-based maps are rarely used, and point-based and line-based maps have a similar use frequency, for all data sources. Point-based maps are slightly more frequent than line-based maps for data from citizens, authorities, and transport services. As for the precise map types, the most frequent across all sources are the 2D graduated symbol map and the 2D flow map.

As for the non-geospatial visualization techniques (Table E.7), the most popular are the heatmap and the line chart. There is no notable difference across data sources, except a higher prominence of the histogram for data from other private companies and for data collected by Internet of Things technologies, and a lower proportion of heatmaps for simulated data.

Which Visualizations for which User?

First, concerning the architecture (Table E.8), the 2D approach is the most frequent in cases where lay citizens are included in the end-users, whereas the 2D+nT approach is much more often used for expert tools. No tool targeting lay citizens combines 2D and 3D maps.

Concerning geospatial visualization techniques (Table E.9), area-based maps are rarely used, and point-based and line-based maps have a similar use frequency across target users, although point-based maps are slightly more frequent than line-based ones in tools destined exclusively to experts. In addition, area-based maps are even rarer seen in works targeting lay citizens (used only once, compared to 20 for works including experts in their target end-users). Overall, the most frequent geospatial techniques are by far the 2D graduated symbol map and the 2D flow map. However, in tools targeting exclusively citizens, the 2D dot map and the 2D network map have a frequency similar to the 2D graduated symbol map and the 2D flow map, respectively.

Lastly, as for non-map techniques (Table E.10), the most frequent ones are the heatmap and the line chart, for both citizens and experts. Low frequencies can be observed for tools including lay citizens in the end-users. This is a result of the fact that the most frequent architecture for lay citizens involves a map without any non-geospatial visualization technique.

7.5 Recommendations

7.5.1 For OGD Publishers

Recommendation 1: Use Consistent Keys Across Datasets

It appeared from the interviews conducted after the OGD use project that the most time-consuming hurdle was to integrate datasets together. This is due to the absence of a common key across the datasets, or to its varying formatting when there is such a key. In most cases, this key consists in a geographic entity such as a neighborhood. It allows, for example, linking a dataset giving the air quality per neighborhood with another dataset giving the traffic density per neighborhood. A recurrent problem is that the neighborhoods are not systematically represented in the same way (e.g. an identifier in one dataset and a name in another), which makes it difficult to combine the two datasets. We therefore recommend the OGD publishers to pay special attention to the consistent representation of data features that can be used as keys to combine datasets. Without going as far as linked open data, which can take time to implement in practice, this would already significantly reduce the impediments related to the *aggregate and transform* phase.

7.5.2 For OGD Portal Developers

Recommendation 2: Involve Citizens in the Development

Regarding mobility data visualizations, involvement of transportation experts to improve the usability of systems was recommended in (Andrienko et al., 2017) and the wider adoption of user-centered approaches in the field was suggested in (Zheng et al., 2016). One observation that stood out from the literature review on intra-city traffic visualization is that validation and end-user involvement seem rather anchored practices in the field. However, we saw in many articles that validation is conducted via case studies only, thus without involving end-users, and that end-user involvement is often limited to defining the tasks. Indeed, in most of the surveyed works, user studies are absent, or deferred to future work (e.g. (Liu et al., 2011; Bogorny et al., 2011; Wörner and Ertl, 2012; Cristie et al., 2015; Skelton et al., 2017; Senaratne et al., 2017)). As for OGD portals more broadly, the study on impediments showed that even users having technical skills can experience difficulties and be discouraged when using OGD. Previous research indicated that carrying usability evaluations is essential to assess whether an interface allows its end-users to carry their tasks in an effective and efficient way (Tory and Moller, 2005). If present in these interfaces, usability issues can hinder the efficiency of the users, or even worse, prevent them from performing some tasks. If the users do not have the obligation to use the system at hand, as it is the case with OGD portals, they may also decide not to use it altogether.

Several techniques exist to collect usability data from users. For example, they can complete a usability questionnaire after using the system. The most widely used is the System Usability Scale (SUS) proposed by Brooke et al. (1996), which is composed of 10 questions. It has the advantage of being highly reliable and quick to complete. Research has also been conducted on interpreting (Bangor et al., 2009) and deriving a learnability measure (Lewis and Sauro, 2009) from the SUS. A more recent and increasingly popular questionnaire is the User Experience Questionnaire (UEQ) (Laugwitz et al., 2008). It consists of 26 items measured on a Likert scale. Whereas the SUS focuses on usability only, the UEQ measures both classical usability aspects (i.e. efficiency, perspicuity, and dependability) and user experience aspects (i.e. originality and stimulation). An example of a more lightweight questionnaire is UMUX-LITE (Lewis et al., 2013), which comprises only two items and might therefore be easier to integrate into a validation protocol. The techniques presented here are among the most cost-efficient, and thus most popular. Many other usability evaluation techniques exist and are detailed in works such as (Hartson and Pyla,

2012) which guides designers in user-centered approaches, and (Elmqvist and Yi, 2015) which details numerous reusable solutions for visualization evaluation. The techniques used should be carefully selected depending on the available resources, the current development stage, and the goals of the study, in full knowledge of the challenges specific to information visualization (Plaisant, 2004) if visualizations are present in the interface.

The SUS has been used to assess the usability of OGD portals (Mitchell and Stobert, 2020). Nonetheless, evaluation techniques have also been created for OGD specifically. Máchová and Lněnička (2017) proposed a list of quality features that can be used to assess the quality of OGD portals. It comprises quality indicators related to the portal (e.g. language, API, documentation) and to datasets (e.g. formats, visualization). The indicators were identified from a literature review. Still based on a literature analysis, Máchová et al. (2018) also developed a benchmarking framework to evaluate the usability of OGD portals. It is composed of 14 usability criteria covering three dimensions, namely open dataset specifications, open dataset feedback, and open dataset request (Table 7.16). In an extensive evaluation of 41 OGD portals using the framework developed by Máchová et al. (2018), Nikiforova and McBride (2021) observed that the criteria for which portals usually achieve the lowest usability score are related to social aspects of OGD, such as communication of the reuse examples and interaction between OGD publishers and OGD users. Tamimi et al. (2017) reviewed OGD usability factors from the literature and defined a list of criteria against which they evaluated the usability of OGD in the United Arab Emirates. The proposed criteria are (1) datasets are complete, (2) missing value are replaced with suitable descriptors, (3) datasets are available without registration, (4) terms and conditions for reusing datasets are available on the portal, (5) datasets are available through API, (6) location-based information is available in GPS coordinates system format, (7) the same data identifiers are used for the whose datasets, (8) sufficient metadata is available, and (9) datasets do not contain unnecessary information. Also from a literature analysis, Hecht (2019) proposed a 70-criteria usability evaluation framework for OGD portals. The criteria cover (1) webpage design, (2) user-centered design, (3) community management, (4) feedback and collaboration, (5) documentation and help, (6) the landing page, (7) the search page, (8) open data principles, (9) metadata, (10) dataset download, (11) rating, and (12) visualization. It is also possible to mix general usability criteria with criteria specific to OGD portals. This is the approach chosen by Wang et al. (2021), who proposed a list of 63 usability criteria derived from the usability heuristics listed by Nielsen and Molich (1990) (general criteria) and from literature on OGD portals (specific criteria).

Recommendation 3: A Tab Dedicated to Lay Citizens on the Portal

Previous research and our requirements elicitation showed that current OGD portals are much more tailored to expert citizens than lay citizens. Indeed, the impediments analysis showed that expert users experienced no major issue related to the interface of the portal. However, there are differences, and in particular conflicts in the requirements we identified for lay and expert citizens. These make it difficult to

Table 7.16: Benchmarking framework for evaluating the usability of OGD portals (reproduced from (Máchová et al., 2018)).

Dimension	Criteria	Description
Open dataset specifications	Description of dataset	Portal provides datasets together with their description and how and for what purpose they were collected
	Publisher of dataset	Portal provides information about organization that published datasets
	Thematic categories and tags	Portal provides thematic categories of datasets to address the main topics covered. It distinguishes categories (themes) from tags (keywords)
	Release date and up to date	Datasets are associated with a time or period tag, that is, date published, date updated and its frequency
	Machine-readable formats	Portal provides datasets formats that are machine-readable and allow easy re-use
	Open data licence	Portal provides license information related to the use of the published datasets
	Visualization and statistics	Portal provides visualization and analytics capabilities to gain information about a dataset, e.g. in charts or visualizations in maps
Open dataset feedback	Documentation and tutorials	Portal provides high quality of documentation and tutorials to help users
	Forum and contact form	Portal provides an opportunity to submit feedback on a dataset from the users to providers and forum to discuss and exchange ideas among the users
	User rating and comments	Portal provides capabilities allowing the collection of user ratings and comments
	Social media and sharing	Portal provides the integration with social media technologies to create a distribution channel for open data and sharing feedback
Open dataset request	Request form	Portal provides a form to request or suggest new type or format type of open data
	List of requests	Portal provides a list of requests received from users, including the current state of request processing
	Involvement in the process	Portal provides capabilities allowing the involvement in the same dataset

integrate all requirements in a unique interface, since some are conflicting. For example, it is not possible to provide a vulgarized content description and technical information at the same time without overloading the interface. On the other hand, openly sharing data is already a time-consuming task for governments with limited resources. Developing a whole new portal could thus be considered a burdening extra task. Therefore, we suggest to OGD portal developers an intermediary solution: to develop a "lay citizens tab," which is a subsection within the portal. This tab would constitute an alternative entry point for the lay citizens on the portal. Ultimately, through continuous learning, lay citizens could progress toward the more "advanced" tab on the portal. For the lay citizens tab, we issue the following recommendations, linked to the five main key differences identified:

- As lay citizens focus primarily on transparency datasets, we recommend portal developers to use indicators from the Digital Transparency Index (as described in (Araújo et al., 2016)) that suggest specific transparency information to be displayed to citizens such as government decisions, payrolls, administrative data, and policy monitoring. These can be used as a basis to fuel the content of the citizens' tab. As lay citizens expect also other datasets, we suggest the transparency datasets to be highlighted on the tab with a "Do you want to know more?" button to access other datasets.
- As lay citizens expect a playful interface when exploring the portal, we recommend, as a basic solution, to provide clear categories and sub-categories with

logos representing the datasets (Deterding et al., 2011). Another interesting improvement lead would be gamification, which consists in using game mechanisms in non-game contexts. Numerous mechanics such as rewards, achievements, defining clear goals, and progress paths, have been successful in engaging users in many domains and could be applied to OGD portals. Blazhko et al. (2017) suggested such mechanisms to improve the communication of OGD on websites. A potential implementation of the immersion mechanism could be to draw a map of the city where the user could explore the different buildings of the city and access relevant datasets. As starting point, we recommend OGD portal developers to constitute a mapping between each of the lay citizens' requirement we identified and gamification mechanisms that could constitute a solution to meet this requirement. A complete list of gamification mechanisms can be found in a recent literature review on the topic by Koivisto and Hamari (2019).

- As lay citizens expect vulgarized content descriptions, we recommend the provision of a manual description for each dataset, understandable and tested with lay citizens. As this is a time-consuming task, we recommend investigating the automatic generation of metadata of the datasets as done by (Assaf et al., 2015). This would leave some fixes to be made afterward, still much less time-consuming than creating all metadata manually from scratch.
- As lay citizens expect a human-readable format when accessing a dataset, we recommend the citizens' tab to allow the export of all relevant information (i.e. raw data, visualizations) in PDF, Word and Excel files.
- There is a demand from lay citizens for visualizations of OGD datasets. However, designing suitable visualizations is a challenging task. We recommend developers of such visualizations to design them in line with considerations for their end-users and their visualization literacy (i.e. their skill of extracting information from visualizations (Boy et al., 2014)). The framework by Munzner (2014) provides usable guidelines on how to make the right design choices given data and users. Regarding mobility data, the guide presented in the previous section gives a broad overview of tested visualizations from which portal developers can draw inspiration.

Recommendation 4: Provide Feedback Mechanisms

Both lay and expert citizens expressed a demand for feedback mechanisms on the OGD portal. They would use them to report errors in data such as missing values or encoding errors, but also to report a lack of data. This would allow the publisher to be aware of issues that are quickly fixable in the dataset to resolve them and in turn improve the quality of the published data. It would also make it possible for publishers to prioritize the data publishing process according to the datasets needed by citizens. Indeed, what data is most valuable is an essential information to ensure an optimal data publishing strategy, but is not always known by the publisher (Crusoe et al., 2020b).

Current OGD portals already include a feedback form. However, we recommend this feature to be pushed further and given more emphasis. Indeed, the requirements elicitation showed that a more contextual mechanism would allow expert citizens to give a feedback that is more relevant and that could be processed faster by the publisher. Following suggestions from the expert interviewees, a feedback interface specific for each dataset could be added, with a predefined list of issues to report.

7.6 Limitations

In this section, we discuss four limitations of the research presented in this chapter. They concern the data collection processes related to the requirements and impediments identification.

7.6.1 OGD User Process Framework as Unique Analysis Grid

The OGD user process framework from (Crusoe and Ahlin, 2019) was relied upon to structure the data collection for both the requirements and the impediments identification. Thus, the content of data collection instruments has been largely influenced by this framework. Other conceptualizations could have been used to structure the OGD use, which would have resulted in other data being collected, and possibly in other recommendations for OGD publishers and portal developers. Nonetheless, we mitigated this issue by not setting this framework as a hard constraint in our data collection. The completeness of the instruments was checked through pre-tests with participants unaware of the user process framework. The participants raised no issue regarding aspects of OGD use not being covered by the instruments. Furthermore, interviews were conducted for requirements and impediments and were semi-structured, thus allowing interviewees to discuss beyond what is covered by the user process model.

7.6.2 Data Collection Heavily Based on Portal from Namur

The OGD portal interviewees were confronted with in the requirements identification is the one put online by the city of Namur. This portal is also one of the few among which students could obtain data in the OGD use project from which the impediments were identified. It is therefore possible that the identified requirements and impediments are "overfitted" to the portal of Namur, and that others could have been observed if a different portal had been studied instead. However, this thesis inscribes itself in the smart city context of Wallonia, and it was therefore important to choose a Walloon OGD portal in order to deliver tailored contributions to Walloon practitioners. Being the most advanced OGD portal in Wallonia, our choice was oriented toward the portal of Namur. Nevertheless, the findings observed for this portal can be generalized to some extent. Indeed, the OGD portal was developed by a private actor, namely OpenDataSoft, which is a leading OGD portal provider in Belgium and in France. The portals provided by OpenDataSoft differ only by minor customization across publishers, making the findings for the OGD portal of Namur easily transposable to other OpenDataSoft portals. It would nonetheless be valuable to repeat the requirements identification with portals developed by other providers to see how the elicited requirements vary. The interview guide used for the requirements identification is provided in full in Appendix D and is directly reusable by researchers willing to engage in this direction.

7.6.3 Motivation Bias in the Impediments Identification

The impediments were studied from 30 students in the context of a graded university project. This does not entirely reflect the real practices OGD use as students were required to use OGD, whereas citizens are normally not coerced to do so. Therefore, we were unable to collect insights on what motivates the use of OGD in the first place. The particular educational context also had an impact on how the phases of the OGD use process were conducted. The project was graded and students had limited time available. This constraint could misrepresent the perceived difficulties through the process, especially at the *motivation and start* phase. Indeed, priorities were put on the other phases, especially the *aggregate and transform* phase, perceived by students as contributing the most to the final output. Altogether, the objective of the students was to deliver on time a visualization or an application to pass the class project, whatever its market viability or power of advocacy. Therefore, the observed impediments might not be entirely generalizable to any OGD use context. Nonetheless, they still provide valuable insights to OGD publishers and portal developers as it helps them to anticipate issues expert users are likely to face. It would be interesting to replicate the impediments identification to a case outside of the educational context. The data collection instruments provided in Appendix C constitute readily usable tools for research interested in pursuing this direction.

7.6.4 Scope of the Visualization Guide

The scope of the visualization guide was restricted to one thematic of OGD, that is, intra-city mobility. However, different approaches were possible. First, instead of focusing on a single theme, the scope could have covered OGD in the broadest sense, irrespective of a specific theme. In this case, the guide would have focused on the common denominator, which breaks down to general visualization design guidelines that could have been collected from scientific articles and books such as (Munzner, 2014). The second possibility would have been to restrict the scope to a few specific datasets instead of a whole theme. In this case, several visualization alternatives could have been designed for the considered datasets and confronted to end-users to collect their preferences. The guide would have consisted in visualization guidelines going in depth but only relevant for a few specific datasets. Thus, expanding the scope would have resulted in guidelines relevant for more datasets but of limited usefulness due to their genericity. On the other hand, restricting the scope would have resulted in guidelines of limited usefulness due to their limited applicability. This is why we opted for the middleground approach consisting in focusing on a data theme.

7.7 Conclusion

Citizen participation as defined in this thesis involves participating to decision-making. Therefore, it is necessary to provide citizens with data they can use to contribute to the decision in an informed way. Pushed by several drivers, more and more governments publish OGD on a wide range of matters. OGD therefore constitutes a promising opportunity to fulfil the information needs entailed by citizen participation. However, it remains largely underused in practice. The goal of this chapter was to offer recommendations for OGD publishers and portal developers helping them to make access to OGD more tailored to lay and expert citizens.

In order to formulate these recommendations, an elicitation of 26 citizens' requirements toward OGD portals was conducted through 20 interviews. The requirements of both lay and expert citizens were extracted, and the differences between both groups were highlighted. The key differences are as follows: (1) before even engaging on the portal, lay citizens expect transparency and information datasets on the portal whereas experts expect niche reusable datasets, (2) when searching for a dataset, lay citizens expect a playful interface whereas experts expect a neutral interface, (3) when they find a dataset, lay citizens expect vulgarized content descriptions whereas experts expect concise technical descriptions, (4) when accessing a dataset, lay citizens expect data in a human-readable format whereas experts expect data in a machine-readable format, and (5) in order to actually use the data, lay citizens seek information through visualizations whereas experts expect raw data. The requirements of expert citizens were refined by analyzing the impediments 30 experts faced in a full-scale OGD use project. Our results show that finding an innovative use for OGD, the lack of metadata describing OGD properly, the lack of support to combine OGD datasets, and the variations in data quality and availability are the most severe impediments.

The requirements analysis showed that a major common ground between lay citizens and experts are the demand for visualizations on OGD portals. We dug deeper into this requirement and developed a guide destined to help portal developers to choose the most appropriate visualization techniques to feature on the portal. The guide is focused on intra-city mobility data due to the popularity of this theme in citizen participation processes.

Finally, the analysis of requirements, impediments, and the visualization guide allowed formulating recommendations for OGD publishers and portal developers.

CHAPTER 8

TACKLING BARRIER 3: PARTICIPATION THROUGH PUBLIC DISPLAYS

8.1 General Introduction

This chapter presents the contributions addressing the third barrier to participation, that is, accessible participation methods, with a special emphasis on participation based on the use of the public displays. As explained in Section 2.3.3, the methods most used in practice such as live meetings and online platforms have entry barriers that call for new methods to compensate their limitations (Challenge for Practice 1). The public display was chosen as object of study due to the peculiarities (i.e. offering an opportunistic, collaborative, and contextualized participation opportunity) it has compared to those methods. These make the public display a good candidate for addressing Barrier 3. Although quite recent, there has been research on using public displays as a participation method. Previous work in this direction mostly report successful results. However, despite its advantages detailed in the scientific literature, the adoption of the public display remains limited in citizen participation initiatives in practice. Therefore, the solution we propose to alleviate Barrier 3 is to study in depth the literature on public displays as a participation method in order to identify leads to expand the adoption of public displays. Indeed, a complete picture of the use of the public display as participation method is missing from the literature (Research Gap 3).

Research Gap 3: No complete picture on public displays and citizen participation.
Challenge for Practice 1: Need to provide new and tested participation methods that can complement existing ones and compensate for their inherent limitations.

The first logical step to undertake to achieve this is the conduct of an in-depth literature review on public displays and citizen participation. Using the Systematic Literature Review methodology, we were able to collect a complete set of research works on the topic and to extract the information needed for the identification of leads. The relationship between citizen participation and public displays was reviewed from two perspectives. First, the "public displays **for** citizen participation" studies the usage of public displays to support citizen participation. Findings pertaining to it indicate the settings (i.e. interaction with the display, participation level supported, citizens reached, and topic of participation) in which public displays have been researched. Second, the "public displays **by** citizen participation" perspective studies how citizens participated in the development of the display. Its findings indicate through which methods citizens have been involved and at which stage (i.e. early development stages or evaluation). The findings resulting from the study of these two perspectives led to the definition of a research agenda structured around four leads for improving the adoption of public displays, namely (1) involving end-users early in the development to better capture their requirements and encourage their acceptance of the display, (2) revisit the usual public display setup to accommodate other forms of participation, and therefore expand the possible uses of the public display, (3) integrate the public display with the other existing participation methods to harness their complementarity, and (4) introduce interface adaptation in public displays to cater for changes in users and environment and in turn provide a more appropriate participation experience.

Then, we addressed the first lead by conducting a questionnaire-based survey research to capture citizens' expectations regarding their involvement in the development of public electronic services. Its scope goes beyond public displays. It concerns the expectations of citizens toward the development of the digital government, which includes the development of digital participation methods provided by the government as a service to citizens, thus encompassing the development of the public display participation method. This survey directly asks citizens their expectations toward the development of the digital government, which has not been done in previous research. This survey identifies the roles citizens are willing to take in the development of digital government, the stages at which they prefer to be involved and the methods they favor for their involvement, as well as the factors that influence them. The results of this survey can be used by public servants to organize the involvement of citizens in the development of public displays in the most appropriate way, according to the profile of the participating citizens.

The second lead we address is the adaptation of public displays. We conducted a further analysis on the corpus of the literature review and we extracted the factors that can both act as motivators and barriers to interaction. Using this foundation, we devised a process model that can serve as a guide for the developers of adaptive public displays by helping them to model relevant adaptation features.

8.1.1 Publications

The content of this chapter is based on the following peer-reviewed scientific publications:
Antoine Clarinval, Anthony Simonofski, Benoît Vanderose, and Bruno Dumas. Public displays and citizen participation: a systematic literature review and research agenda. **Transforming Government: People, Process and Policy**, 15(1):1–35, 2021c

- This article presents a literature review of public displays and citizen participation. It studies the connection between the two in a dual perspective. First, the "public displays **for** citizen participation" studies the usage of public displays to support citizen participation. Findings pertaining to it indicate the settings (i.e. interaction with the display, participation level supported, citizens reached, and topic of participation) in which public displays have been researched. Second, the "public displays **by** citizen participation" perspective studies how citizens participated in the development of the display. Its findings indicate through which methods citizens have been involved and at which stage (i.e. early development stages or evaluation). The findings resulting from the study of these two perspectives led to the definition of a research agenda structured around four leads for improving the adoption of public displays.

Anthony Simonofski, Antoine Clarinval, Benoît Vanderose, Bruno Dumas, and Monique Snoek. What influences citizens' expectations towards digital government? an exploratory survey. **Digital Policy, Regulation and Governance**, ahead-of-print, 2021b

- This article presents a questionnaire-based study aiming to identify which factors influence the roles citizens are willing to take in a digital government. The roles were defined according to (Simonofski et al., 2017b). The examined factors include age, gender, occupation, education, digital literacy, government level, and frequency of use of other e-services. Through a statistical analysis on data collected from 203 citizens, numerous significant relationships involving most of the listed factors could be found. The article also contributes a reusable survey instrument and discusses how some of the relationships can be put into action by public servants.

Antoine Clarinval, Bruno Dumas, and Benoît Duhoux. Supporting citizen participation with adaptive public displays: a process model proposal. In **Adjunct Proceedings of the French-Speaking Conference on Human Computer Interaction**, pages 1–11, 2019

- This article presents a process model destined to guide designers of adaptive public displays. The model proposes to structure an adaptation around the five W questions. It is based on motivators and barrier to interaction with displays extracted from the articles reviewed in (Clarinval et al., 2021c).

8.1.2 Outline

This chapter is structured as follows. Section 8.2 gives an overview of the current research on public displays and citizen participation and presents a research agenda comprising four leads for expanding their adoption. Section 8.3 delves deeper into one of these avenues and presents the survey research on citizens' expectations toward their involvement in the development of digital government services. Another avenue is addressed in Section 8.4 which describes a process model supporting the development of adaptive public displays. The methodology followed for developing these contributions is detailed in their respective dedicated sections. Lastly, Section 8.5 discusses the limitations of the contributions presented in this chapter.

8.2 Literature Review on Citizen Partipation and Public Displays

8.2.1 Methodology

This section details the review protocol that guided the survey. It was defined in line with the systematic literature review guidelines (Kitchenham and Charters, 2007; Petersen et al., 2008). The need for a review was discussed in Chapter 2.3.3. The remaining steps, namely defining the scope and research questions, the search terms and the digital libraries where the literature search was conducted (*planning the review*), the results of the search (*conducting the review*), as well as how the findings are reported in Section 8.2.2 and Section 8.2.3 (*reporting the review*), are successively discussed in the following.

Scope and Research Question

The research objective is to study how current research reports reflect on using public displays in the smart city by examining the state of the art of this domain from two angles: how citizens participate in the development of public displays (public displays *by* citizen participation), and how public displays foster citizen participation on urban issues (public displays *for* citizen participation).

To better frame the scope of the literature review, we rely on the definitions of citizen participation and of public display, that were provided in Section 2.2 and 2.3, respectively. Citizen participation is defined as the process of including citizens in government decision-making. In the same line as Callahan (2007), political participation (i.e. voting) and citizen engagement in public life (i.e. referring to the smart people dimension from (Giffinger and Gudrun, 2010)) are excluded from this definition. Public displays are interfaces deployed in the public space to be accessible by any passerby (Vande Moere and Hill, 2012). They are the technological counterpart of paper posters and have therefore initially been used for advertising or event promoting purposes (Thiel, 2015).

Research Question Refinement

Both the *for* and *by* angles cover multiple perspectives, they were thus broken down into specific research questions (SRQ), each tackling one perspective. On the *for citizen participation* side, the questions tackled are the interaction modality, the level of participation achieved by the display, the socio-demographic characteristics of the participating citizens, and the topic of the displayed content (i.e. the urban issue at hand). On the *by citizen participation* side, the involvement of end-users in the early stages of the development and the type of user evaluation that was conducted, are addressed. The subsequent paragraphs detail how the relevant information for each SRQ was extracted from the surveyed papers. The sets of categories guiding the process for each SRQ are summarized in Table 8.1.

SRQ 1: How do citizens interact with public displays? The goal of this SRQ is to understand through which interaction modalities citizens interact with public displays, with a focus on the *input* interaction modalities. It is a central aspect of public displays in the context of citizen participation, as it determines whether citizens will be enticed to interact with a display or not.

In this review, the four interaction modalities listed in (Ardito et al., 2015) are considered, as this classification was proposed specifically for interactive public displays. *Touch* refers to manipulating elements by touching them directly on the display. An *external device* can also be used as an intermediary to convey information to a public display. Well-known examples include mobile devices such as smartphones. *Tangible objects* are physical counterparts of public display elements which can be manipulated to affect the display. Lastly, users can convey information to a public display through *body movements* such as gaze and gestures.

SRQ 2: What is the level of citizen participation achieved through public displays? Citizen participation is often characterized as a spectrum where the decision power on an issue at hand is balanced between citizens and elected officials. The influence of citizens can range from none (being informed of the decision taken by officials) to total (all decision power is delegated to citizens), with intermediate levels describing, for instance, situations where elected officials and citizens collaborate together toward a common agreement. Arnstein's ladder of citizen participation (Arnstein, 1969) was used to characterize the participation levels achieved by the surveyed works. It consists of an 8-tier ladder describing eight levels of citizen participation. They are detailed in Section 2.2.

For the purpose of this SRQ, it is also important to evaluate the impact of the participation. For the surveyed articles achieving a participation level of consultation or above, the way they report consideration of citizens' input by the authorities was extracted. It should be noted that some public displays deployed by researchers do not have the goal to make use of the citizen data they collected, but rather to inform good practice for developing future systems. Nonetheless, informing citizens on the impact of their participation is important, as citizens cannot be expected to distinguish between those public displays deployed solely for collecting good practice insights from those supporting real participation.

SRQ 3: Who does effectively participate through public displays? Citizens differ by many socio-demographic characteristics such as background, gender, age, etc. Hence, when considering the deployment of public displays, the question of "who participates" (i.e. what are the characteristics of the citizens who actually use public displays for participation purposes) is important to study.

The aim of this third SRQ is thus to study whether the socio-demographic characteristics of participating citizens are reported in the surveyed papers. The considered characteristics were mostly extracted from the cited related literature and include, but are not limited to, *age*, *gender*, *income*, *ethnicity*, *occupation*, *digital literacy*, *impairments*, *education*, *family situation*, and *local* (i.e. whether the citizen lives in the area concerned by the public display).

SRQ 4: Which urban issues are covered by public displays? The participation of citizens can be asked for a wide range of matters concerning the urban life. The goal of this fourth SRQ is to study which urban issues current public displays enable citizens to participate on.

In this review, six categories of urban issues are considered, following the six smart city dimensions listed by Giffinger and Gudrun (2010). These dimensions were used for this research question because they provide a convenient way of classifying urban issues. As these dimensions are broad by nature, it is always possible to assign a dimension to an issue tackled by a public display.

SRQ 5: How are public displays evaluated? The fifth SRQ aims at characterizing the evaluation process underwent by public displays. In order to provide an in-depth analysis of this aspect, the work of Alt et al. (2012), who listed five evaluation paradigms for public displays, was used as categorization basis. *Ethnography* and *asking the users* relate to the design phase of the display development (i.e. requirements engineering, interface design). *Field study*, *lab study*, and *deployment-based research* are used to evaluate a public display prototype. The focus of this SRQ is on the evaluation of public display prototypes. Therefore, the ethnography and asking users paradigms are set aside, as they relate to earlier stages of the development. Lab studies are conducted in a controlled setting, whereas field studies and deployment-based research are carried in the wild (that is, in the case of public displays, in the urban environment). Unlike field studies, deployment-based research involves iterating on the public display prototype to improve it during its deployment. Thus, this evaluation paradigm usually entails long (several months to several years) deployments. In addition, the authors distinguish between three types of study, namely *descriptive*, *relational*, and *experimental*. Descriptive studies are reported narratively, by describing what is happening during the evaluation. Relational studies analyze the correlation between two variables without considering causality (i.e. which variable influences the other). Experimental studies determine causality relationships between several variables, and thus require comparison between deployments. The results of relational and experimental studies are supported by statistical significance tests. In this review, this twofold characterization (i.e.evaluation paradigm and type of study) was followed to report the user evaluation type for each article.

SRQ 6: How do citizens participate in the early stages of the development of public displays? As discussed earlier, Alt et al. (2012) list two paradigms used in the early stages of the development of public displays. For each surveyed article, whether citizens were involved through the *ethnography* or the *asking users* paradigm was noted. Ethnography consists in the investigation of a social setting without intervention, whereas asking the users implies getting answers to questions from them.

Another extracted information is the participation method through which citizens' insights were collected following the asking users paradigm. The eight methods listed by (Simonofski et al., 2017a) were considered, namely *interviews and group discussions, representation in project team, workshops, surveys, dedicated software, social media, innovation ecosystem*, and *prototyping*.

Table 8.1: Classification scheme used to extract information from the surveyed articles

Public displays *for* citizen participation		
SRQ 1	modality	touch – external device – tangible – body movements
SRQ 2	level	manipulation – therapy – informing – consultation – placation – partnership – delegated power – citizen control
	feedback	feedback on participation – no feedback on participation
SRQ 3	charact.	age – gender – income – occupation – education – digital literacy – ethnicity – local
SRQ 4	urban issue	economy – people – governance – mobility – environment – living
Public displays *by* citizen participation		
SRQ 5	paradigm	lab study – field study – deployment-based
	type	descriptive – relational – experimental
SRQ 6	paradigm	ethnography – asking users
	method	interview or group discussion – representation in project team – workshop – survey – dedicated software – social media – innovation ecosystem – prototyping

Search Terms

The research question of this review was translated into a machine-readable query following the aforementioned PICOC framework (Petticrew and Roberts, 2006). Two groups of keywords were defined for the Population and the Intervention. Since this survey concerns the use of **public displays** for and by **citizen participation**, the latter relates to the Population and the former to the Intervention. The selection of keywords regarding citizen participation draws from (Simonofski et al., 2017a), a systematic literature review in which citizen participation is the Intervention. As for the terms relating to public displays, they result from previous explorations of research on public displays and other related fields such as information visualization and media architecture. They were broken down into two subgroups, relating respectively to the **public** and **display** concepts. The term groups were refined throughout the article search and selection processes with missed relevant keywords. The final query was applied to the title and keywords fields, alike for all searched digital libraries. It is composed of three groups as follows:

```
(Application OR Visualization OR Visual OR Display OR Interface
OR Screen OR Platform OR Media OR Device OR Dashboard)
AND
(Ambient OR Public OR Urban OR Pervasive OR Situated
OR Ubiquitous OR Architecture OR Architectural)
```

```
AND
(Participation OR Participatory OR Engagement OR Involvement
OR Inclusion OR Collaboration OR Collaborative OR Cooperation
OR Cooperative OR Co-creation OR Cocreation OR Co-design
OR Codesign OR Co-production OR Coproduction OR Debate OR Empower
OR Empowerment OR Participative OR Civic OR Poll OR Vote
OR Opinion OR Citizen OR Awareness)
```

Selected Digital Libraries

The search was performed on three digital libraries, namely ScienceDirect, IEEEXplore, and ACM Digital Library. The choice of ACM Digital Library and IEEEXplore was motivated by the popularity of ACM and IEEE among researchers who work in computer science related domains (Kitchenham et al., 2015). In order to capture research works from the citizen participation research field, ScienceDirect was selected, as it is not specific to computer science topics. The selected digital libraries cover both conference and journal papers, which are the main research publication channels.

Inclusion and Exclusion Criteria

In order to filter the research works relevant to the research question of this paper, inclusion and exclusion criteria were defined. An article is considered relevant if it satisfies all the inclusion criteria and none of the exclusion criteria. As for the inclusion criteria, one general criterion was defined due to the broadness of the research question of the review. A research work is considered relevant if it presents an application of public displays in the context of citizen participation. As for the exclusion criteria, they are defined with their rationale as follows:

(i) **Articles not written in English**.

(ii) **Duplicated articles**.

(iii) **Articles published before 2008**: previous explorations of the field indicated that few relevant research was conducted before 2008. Research on citizen participation in smart cities was largely sparked by the criticism from authors such as Hollands (2008) who advocates a focus on citizens' needs instead of technology in cities striving to develop solutions to the urban issues they face. Also, a previous survey (Ojo et al., 2016a) showed that the growth of the smart cities field is recent, with a 200% increase in the publication volume between 2009 and 2016. Therefore, a time frame of 11 years should provide a representative vision of the research on public displays and citizen participation.

(iv) **Secondary studies**: secondary studies refer to reviews of existing research in a field. The secondary studies gathered through the articles search are thus covered as related work in Section 2.3 and are not included in the body of research surveyed in this study.

(v) **Poster track publications**: articles published in poster tracks are not included because they describe research in early stages or do not provide enough information to be analyzed according to the classification scheme.

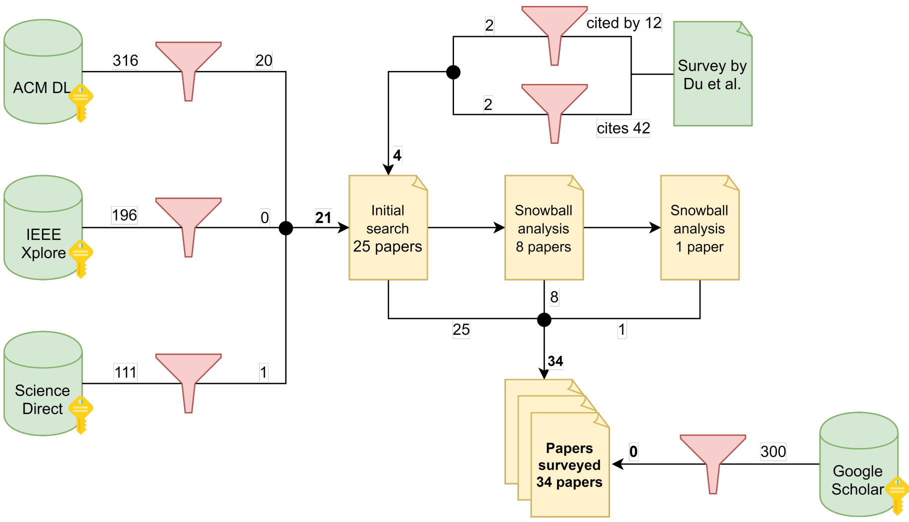


Figure 8.1: Methodology followed to conduct the review. First, the keyword search (indicated by the key symbol) was performed on ACM DL, IEEEXplore, and Science Direct. The coverage was completed by analyzing the papers citing and cited by Du et al. (2017). 25 relevant articles were extracted. After conducting a snowball analysis on the bibliographies of these 25 articles, 8 new relevant articles were added. A snowball analysis on these 8 returned one additional relevant article, which had no new relevant article in its bibliography. The 34-article set thus formed was completed by a keyword search on Google Scholar which yielded no new relevant article in the first 300 results.

Extraction of Relevant Works

In total, the search on ScienceDirect, ACM Digital Library, and IEEExplore yielded 623 papers congruent with the search terms. After analyzing their meta-information and abstract, 21 articles passed the inclusion and exclusion criteria check. The distribution per digital library is shown in Table 8.2. It can be observed that the percentage of relevant articles found among those returned by the search engine varies significantly among the surveyed digital libraries. While ACM Digital Library reaches 6.3%, it is much lower for IEEEXplore and ScienceDirect. The reason for this is that several prominent conferences in the field such as CHI (5 of the surveyed papers), PerDis (5), and DIS (5) are sponsored by the ACM. For ScienceDirect, two combinations of keywords yielded many articles irrelevant for the review. These are articles about *social media* use and *public opinion* analysis. For IEEEXplore, the search returned many articles discussing *public opinion* analysis systems, *collaborative ubiquitous* systems and software *architecture*.

Furthermore, since the scope of this paper is close to the one of the survey by Du et al. (2017), the articles cited in and those citing it were checked as well. In total, 42 (resp. 12) articles were cited by (resp. citing) Du et al. (2017). 8 among the 42 articles cited by Du et al. (2017) passed the inclusion and exclusion criteria check,

Table 8.2: Relevant studies per digital library after the initial search (the articles extracted from (Du et al., 2017) and those from the snowball analysis are not included)

Digital library	Articles returned	Relevant articles	% of relevant articles
ScienceDirect	111	1	0.9%
ACM Digital Library	316	20	6.3%
IEEEXplore	196	0	0%
Total	**623**	**21**	**3.4%**

6 of which were already included in the 21 returned by the digital libraries. As for the 12 citing (Du et al., 2017), 2 passed the inclusion and exclusion criteria check and were not captured by the digital libraries. Thus, the search yielded a total of 25 articles, 21 extracted from the search on digital libraries and 4 from (Du et al., 2017).

A snowball analysis (i.e. a search on the selected articles' bibliographies) was conducted on the 25 articles to collect additional articles and therefore ensure a more complete coverage. It yielded 24 relevant articles, 16 of which were already included in the 25 initial. Thus, in total, 8 new relevant articles were yielded by the snowball analysis. Another snowball analysis was conducted on these 8, which returned 13 relevant articles, 12 of which were already captured. The 1 remaining article was added and had no new relevant article in its bibliography. Therefore, the body of reviewed research contains the 25 articles yielded by the initial search, as well as the 9 articles returned by the successive snowball analyses, for a total of 34 publications.

The compliance to the search terms was not checked for the articles collected through the snowball analysis and those extracted from (Du et al., 2017), as their presence in the bibliography of a relevant article serves as initial filter instead. Rather, their relevance was determined solely by the criteria.

After aggregating all the relevant articles, a search was performed on Google Scholar as a final check of coverage completeness.

Categorization Process

The information relating to the six SRQ was extracted from the surveyed papers by two researchers. Each of them read the paper independently and completed a memo containing the information. The results were then confronted for each paper. Disagreements were solved by involving a third researcher in the process, who read the concerned paper and completed the memo as well. The results were then discussed by the three researchers who reached a consensus.

Coverage Assessment

A final check was done by performing a keyword search on Google Scholar. Although 1,679 results were returned, the review was restricted to the first 300 for two reasons. First, Ardito et al. (2015) noted that their search for literature on interactive public displays on Google Scholar yielded articles of little relevance beyond the first 150 results. Second, no additional relevant article was found after reviewing the first 300 articles, as all relevant results returned by Google Scholar were already captured at this point.

Figure 8.1 presents a visual overview of the article search process.

Reporting the Review

The next section presents the findings of the literature review, successively for each SRQ. The numbers relating to the categorization process are given, illustrated by examples from the surveyed articles. The information classification extracted for the 34 articles are available in Appendix F.

8.2.2 Findings

Interaction Modalities (SRQ1)

The first observation regarding SRQ1 is that 33 of the 34 surveyed displays provide interaction features. Among these, 10 offer two or more interaction modalities, which are in 6 cases equivalent (Coutaz et al., 1995) alternatives. The most popular modality (see Figure 8.2) is the use of an external device (25 of the 33 articles), followed by touch (8), voice (4), body movements (3), and lastly tangible artifacts (1). The most popular external devices in the surveyed articles are physical buttons (12) and mobile phones (7). Other devices (e.g. rotatory controls, tablet, mouse) are used in marginal cases.

In some of the surveyed studies, alternatives to interaction with the public display were advertised on the display itself (Schiavo et al., 2013b; Baldauf et al., 2014; Taylor et al., 2012; Hosio et al., 2014a). These include, for example, voting via SMS, Twitter, e-mail, or a web platform. However, all the surveyed articles that reported setting up such alternatives also reported that they were forsaken in favor of the interaction with the display.

Level of Participation Achieved (SRQ2)

Only three of the eight levels defined by Arnstein are represented in the surveyed papers (see Figure 8.3). They form the spectrum of tokenism (Arnstein, 1969), which covers real participation with no decision power delegated to citizens. Hence, none of the surveyed articles presents a display through which citizens can exercise decision-making power.

Among the 34 surveyed displays, the most common participation level reached is by far consultation (30), followed by placation (2) and informing (2). In 14 of the

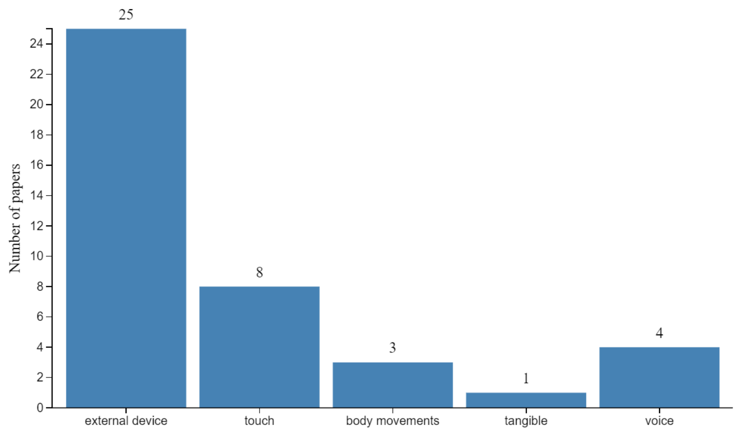


Figure 8.2: Interaction modalities offered by public displays (SRQ 1)

30 displays achieving the consultation level, the user input consists in a multiple-choice answer such as a 3-point opinion scale or a yes/no answer. It shows that the participation reached through public displays frequently consists in one-way flows of information and simple answers for which consideration by the authorities is not guaranteed.

Although 32 articles present displays supporting a consultation participation level or higher, only 6 report on how participating citizens received feedback from their input. Examples of feedback include promise of action (Taylor et al., 2012), discussions with officials at the display location (Schroeter, 2012; Mahyar et al., 2016) or remotely (Schroeter and Houghton, 2011; Hosio et al., 2014a), and online publication of accepted ideas (Noyman et al., 2017). In (Fredericks et al., 2015), the authors reported that the collected citizens' opinion drove decisions, but the article does not mention whether citizens where informed of that.

Socio-Demographics of Participants (SRQ3)

Overall, few articles report extensively on socio-demographics, 11 articles not discussing any. Table 8.3 shows the socio-demographic characteristics reported in the surveyed articles. Only age (20 articles) is covered by more than half of the surveyed papers. Gender comes in the second place, with reports in 15 articles. The background of users is considered in various forms such as previous engagement (5), digital literacy (4), and education level (2). Overall, users' background was reported in 9 papers. Whether users are locals of the area concerned by the public display (7) and their occupation (7) come next in the ranking. Other socio-demographic characteristics such as family situation and ethnicity are reported marginally when not completely overlooked.

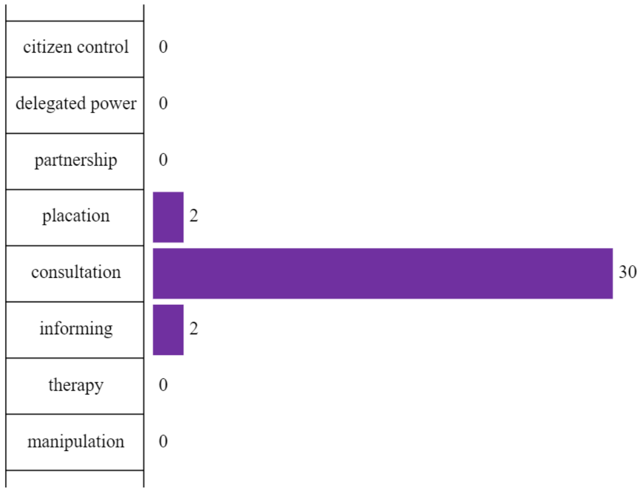


Figure 8.3: Participation levels supported by public displays (SRQ 2)

Table 8.3: Reported socio-demographics from the 34 surveyed papers (SRQ 3).

Citizen characteristic	Reports in articles
Age	20
Gender	15
Local	7
Occupation	7
Previous engagement	5
Digital literacy	4
Education level	2

Urban Issues Tackled (SRQ4)

Several articles have positioned their issue at hand as an urban planning one. In these instances, the goal of the urban planning was used to extract the associated smart city dimensions. For instance, one urban planning scenario studied in (Du et al., 2020) concerns the creation of a book store in a campus. In this case, the goal of the urban planning is to create a cultural facility and the scenario therefore refers to the living dimension.

An interesting observation is that 14 of the 34 surveyed papers tackle more than one urban issue. The majority of the surveyed displays ask citizens to answer questions, it is therefore frequent to find several urban issues in the pool of questions asked. For the concerned articles, each urban issue that could be inferred from the questions asked was noted. In the cases where the questions asked where not reported by the authors, the urban issue was labeled as *Unspecified*. This concerns 8 of the 34 articles.

Another observation is the prominence of the living urban issue, which is tackled by 18 displays (see Figure 8.4). It is due to the broad nature of this issue, as it regards the well-being of citizens in general. Mobility (10), governance (7), economy (6), and environment (6) are tackled on several occasions, while the people (1) dimension seems left behind.

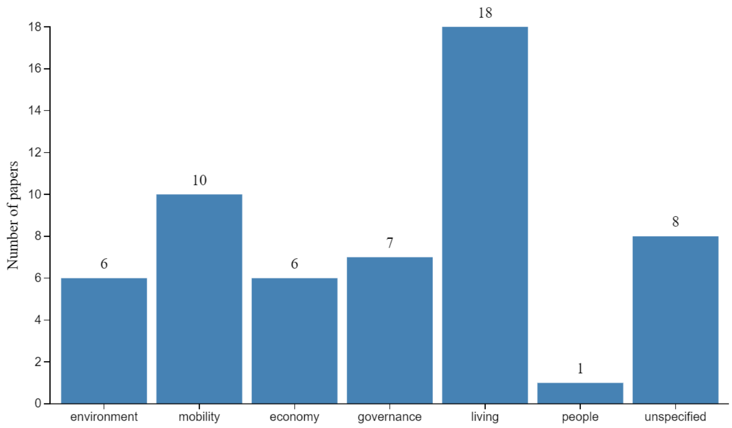


Figure 8.4: Urban issues tackled by public displays (SRQ 4)

Public Displays Evaluation (SRQ5)

In this survey, the evaluations underwent by public displays were characterized by a paradigm and a type, following (Alt et al., 2012). Several combinations can be used for a single display. For example, in (Hosio et al., 2014a), the authors conducted a descriptive lab study as part of a descriptive deployment-based research in order to evaluate a specific feature of their system in a controlled setting. In such cases, each combination was counted once. In total, 33 of the 34 surveyed papers conducted an evaluation of the presented display (Table 8.4).

Table 8.4: Evaluations underwent by the surveyed public displays (SRQ 5).

Paradigm	Descriptive	Relational	Experimental	**Total**
Lab study	2	0	1	**3**
Field study	28	1	0	**29**
Deployment-based	2	0	0	**2**

Evaluation type Only 1 of the surveyed articles conducted a relational study and 1 carried out an experimental study. Conversely, 31 of the 34 articles relied on the descriptive evaluation type.

Evaluation paradigm The field study is by far the preferred paradigm, being implemented in 29 of the surveyed papers. Conversely, deployment-based evaluations and lab studies were carried out in only 2 and 3 articles respectively.

Participation in Development (SRQ6)

End-users were involved in the early development stages in 16 of the 34 articles. More precisely, researchers resorted to ethnography in 3 articles and the asking users paradigm was used in 14 articles. The methods used for this purpose were interviews or group discussions (12), workshops (5), and questionnaires (3).

Furthermore, 18 of the surveyed papers reported involving other stakeholders, in addition to the end-users. The participation in development of stakeholders other than citizens is advocated by Simonofski et al. (2017a). The stakeholders involved were grouped into three categories. First, those who can use the citizen feedback collected through the display to make decisions (e.g. elected officials, city planners), referred to as *officials*. Second, experts in interface and visualization design, labeled as *HCI experts*. Third, local champions and community activists, referred to as *champions*. The most frequently involved stakeholders in the surveyed articles were officials (11), champions (5), and HCI experts (2).

8.2.3 Research Agenda

This section elaborates on four research directions informed by the findings of the literature review. For each direction, the discussion starts with the insights from the review and is completed by related literature.

Research Direction 1: Large-Scale Methods for Improving Participation in Early Development Stages

Only 16 of the 34 surveyed articles involved citizens at the early stages of the development, and even fewer reported having done so iteratively. Furthermore, only small-scale methods are used to support the participation of citizens in the early stages of the development, namely interviews and group discussions, workshops, and surveys.

Focus groups, interviews, and workshops allow participation in development on a small scale (Simonofski et al., 2017a), and therefore may hamper representativity. However, previous research showed that involving a representative sample of the population living in the vicinity of a public display is critical to its acceptance by citizens (Memarovic et al., 2013). A compelling example is a public display in Brussels that was deployed in an area with a high unemployment rate (Vande Moere and Wouters, 2012). Due to a discrepancy between the *content* and the *people* aspects (Schroeter et al., 2012) the display was negatively perceived by the locals for advertising luxury shops, and was vandalized as a result. One solution to improve this representativity issue is to favor the use of larger-scale participation methods such as living labs and dedicated software.

Living labs Living labs (Bergvall-Kareborn and Stahlbrost, 2009) allow longer-term participation. Hence, they can accommodate the participation of more citizens, and iterative development processes. This is highly valuable in the context of public displays development. Indeed, it is necessary to go through multiple development cycles for end-users to think beyond their pre-existing interaction mental models and reflect on other interaction modes than the ones they are used to.

Dedicated software Dedicated software allow involving a larger group of users at an early stage of the development. Two types of software are particularly relevant: crowd-centric requirements engineering (CCRE) platforms and e-participation platforms. CCRE platforms apply the crowdsourcing paradigm to elicit, negotiate, and prioritize requirements from users about a future system (Snijders et al., 2014). They would be relevant to understand the requirements of citizens about a public display. On the other hand, e-participation platforms allow collecting citizens' needs and ideas about a determined issue (Berntzen and Johannessen, 2016). By analyzing the issues and ideas raised on the platforms, the designers of a public display could submit questions to the citizenry more aligned with their current concerns.

We address this lead in Section 8.3.

Research Direction 2: Supporting Higher-Level Participation

The participation levels reached by the surveyed public displays are information, consultation, and placation. The most frequent participation level reported in the surveyed papers is consultation, often in a simple form such as a multiple-choice questions or selecting a smiley to express an emotion. The surveyed public display supporting the highest participation level relied on tangible interaction (Noyman et al., 2017), and is the only one which used this interaction modality.

Nonetheless, public displays have high potential for supporting citizen participation different than the usual informing or multiple-choice consultation. Their situated nature allows contextualizing urban issues and they are well-suited for collaborative interaction. Indeed, a recurrent observation in public display research is that users passing by in groups are more likely to approach a public display (Schiavo et al., 2013b; Veenstra et al., 2015; Claes and Vande Moere, 2013; Memarovic et al., 2012; Hosio et al., 2012). Two aspects of a public display setup can be acted upon to ease the support of high participation levels: the display orientation and the interaction modality.

Display orientation The usual setup of public displays implies a vertical orientation (Ardito et al., 2015). However, a study on touch interaction by Pedersen and Hornbæk (2012) showed that vertical displays are more physically tiresome to use than horizontal ones. It was also reported by Hosio et al. (2014a) that users found it physically painful to type long messages with a virtual keyboard on a vertical display. Thus, the orientation of the display has to be carefully considered when designing a system for higher levels of participation, as the interaction sessions in these cases are expected to last longer than for simple form consultation. A possibility is the combination of differently oriented displays, as proposed by (Mahyar et al., 2016). In their study, the authors suggest to reflect the interaction with a touch table on a vertical display. A similar participatory system could be envisioned to make the most of both vertical and horizontal displays. The horizontal display, less physically demanding, would be the meeting point for citizens willing to interact with the system, whereas the vertical display could draw passersby's attention and invite them to participate as well.

Interaction modality Tangible interaction is especially suited for collaborative interaction (Schneider et al., 2010), which is needed to reach higher participation levels. Tangible interaction also has high potential for discussing urban issues. The elements of a city (buildings, street lights, etc.) have a straightforward counterpart in the form of physical artifacts and are appealing to a large public. For example, its interest for urban planning was studied by previous works (Underkoffler and Ishii, 1999; Ishii et al., 2002) proposing to leverage tangible interaction to study the shadow projections made by infrastructures. Finally, tangible artifacts are a playful way of interaction (Hornecker and Buur, 2006; Marshall, 2007). In the public display research, playfulness was identified as a motivator for participation (Hespanhol et al., 2015; Hosio et al., 2012; Wouters et al., 2014; Gabrielli et al., 2011).

Research Direction 3: Creating a Citizen Participation Methods Ecosystem

In the surveyed papers, the characteristics of the participating are rarely reported beyond age and gender, omitting other essential characteristics such as digital literacy and previous engagement.

Public displays are not the only existing citizen participation method, and therefore an essential question is their added-value compared to these methods. Previous research showed that public displays allow gathering more input from citizens than paper forms and web e-participation platforms (Goncalves et al., 2014). This is due to their ability to draw attention from numerous passersby and to invite them to interact. However, the input received through public displays is far noisier than data collected from paper forms and web platforms. This suggests that citizen participation methods are better used in combination with each other in order to reach as many citizens as possible and ensure the validity of the input collected regarding representativity. For instance, it was observed by Goncalves et al. (2014) that public displays can successfully serve as attention drawer in a public setting to invite citizens to participate using nearby paper forms. In order to integrate public displays within the ecosystem of citizen participation methods (that is, combining efficiently public displays with these methods in a complementary way), it is essential to understand which citizens interact with deployed public displays, and thus to have socio-demographic information about the actual users of these displays. Indeed, Simonofski et al. (2021c) identified citizens' characteristics as a context factor impacting citizen participation strategies.

Although citizens' characteristics are tedious to collect given their private nature and the fact that users usually interact with public displays in an opportunistic way, it is essential to collect them. Previous engagement on urban issues is an example of information that is not too sensitive to ask users about but is still of great value to understand the place of public displays in the citizen participation ecosystem.

Research Direction 4: Handling a Changing Context

This research direction also emerges from the fact that the characteristics of participating citizens are reported infrequently and not in much detail. The variability in the users and the highly dynamic nature (e.g. weather, crowd) of the urban environment in which public displays are deployed raise the challenge of maintaining an optimal experience for all citizens at all times. Interface adaptation (Thevenin and Coutaz, 1999) has for long been proposed as a solution to handle variations in the context while preserving the usability of the interface. In the context of public displays, interface adaptation provides opportunities for developing systems able to entice more citizens to participate. Some previous work has focused on the adaptation of public displays according to one context factor such as the distance between the user and the display (Ballendat et al., 2010; Greenberg et al., 2011), the user interest in the display (Schiavo et al., 2013a), or the height of the user (Parker et al., 2017). However, no research has been conducted on developing adaptive public displays for citizen participation purposes. Nonetheless, this is a research direction worth pursuing, although in full knowledge of the challenges it involves such as managing conflicts in the adaptations driven by changes in the context (Mens et al., 2017) and maintaining the user's trust in such a changing interface (Kurdyukova, 2011). We address this lead in Section 8.4.2.

8.3 Citizens' Preferences for Participating in Development

The first lead discussed in the research agenda "Large-Scale Methods for Improving Participation in Early Development Stages" lead is presented. It results from the public displays by citizen perspective and stems from the observation that citizens are not sufficiently involved in the early stages of public displays development. Such involvement is critical to expanding the adoption of public displays as the match between the display and its audience (that is, the citizens) is essential to its acceptation (Schroeter et al., 2012). It is therefore also essential to its success as a participation method, success which will in turn result in adoption of the public display method in other contexts.

That match can only be achieved by eliciting the requirements of the citizens regarding the display, which should be done early in its development through appropriate methods. When discussing the first lead in the research agenda, our stance was largely grounded in existing literature, which led us to propose large-scale methods for citizen involvement in early development. Therefore, we aimed at completing this discussion based with data collected directly from citizens. Since few citizens are familiar with participation through public displays due to their low adoption, we needed to take a step back from public displays to view the bigger picture and set our focus on digital government. We consider that public displays for citizen participation are part of the digital government as they constitute electronic services provided by governments to citizens to allow them to participate. We studied the expectations of citizens toward digital government or, in other terms, the roles they are willing to take in the digitalization process of their government, or the shape of their involvement that they envision). The approach we followed consists in administering a questionnaire to reach a sample size large enough to draw significant conclusions on the factors influencing these expectations.

Section 8.3.1 details the methodology of this survey research by setting the theoretical ground and the research design that framed the research questions and the questionnaire elaboration. It describes the questionnaire distribution approach and the analysis techniques that have been conducted on the data. These analyses uncovered numerous significant relationships on citizens' expectations that are presented in Section 8.3.2. Finally, Section 8.3.3 provides recommendations to public servants to help them to put the findings into action.

8.3.1 Methodology

Theoretical Grounding

There are multiple views on how digital government should be defined in research and implemented in practice, and thus on the different possible roles for citizens. Previous research has already formalized these different roles. We will rely on the categories identified in a previously performed systematic literature review (Simonofski et al., 2017b). We chose these categories as they are consistent with other formalizations of citizens' role in digital government (Berntzen and Johannessen, 2016; Callahan, 2007; Simonofski et al., 2017a). Indeed, these studies separate the role of customers and participants for citizens, as underlined in the introduction. Furthermore, within the "participants" role, they also differentiate between the participation in democratic life and the coproduction of public services. The three roles retained in this paper are thus the following:

- **Citizens as Customers**: citizens are considered as recipients of digital government services. Thus, in this role, digital government refers to the actions taken to improve service quality, efficiency, and effectiveness thanks to ICT to increase citizens' satisfaction (e.g. citizen relationship management system). This role is further described in (West, 2005; Veiga et al., 2016; Eyob, 2004).
- **Citizens as Democratic Participants**: citizens are considered as active participants in the decision-making processes of government. Thus, digital government refers to the actions performed, with the help of ICT, to facilitate the impact of citizens in decision-making (e.g. e-voting systems). This role is further described in (Porwol et al., 2016; Sundberg, 2019; Macintosh, 2004).
- **Citizens as Coproducers**: citizens are considered as holders of ideas and expertise that can assist governments in their daily tasks. This assistance can take place in the development of a digital government service (e.g. communication of requirements), or through the help of an existing digital government service (e.g. FixMyStreet (Pak et al., 2017)). This role is further described in (Simonofski et al., 2019b; Axelsson et al., 2010).

While these different roles have already been discussed by other authors from different research fields, to our knowledge, no work has reported on a study asking directly to citizens what they expect from a digital government (in other words, which roles they are willing to take on) and identifying which factors influence their expectations. However, several previous studies have performed research in a similar direction. In their analysis of the motivations of citizens to participate, Wijnhoven et al. (2015) have conducted a survey to better understand which dimensions influence citizens. Furthermore, Distel and Becker (2017) suggest to investigate in a deeper way the abstract “citizen” concept, attempting a segmentation of the population in relation with e-government services use. Naranjo-Zolotov et al. (2019) reported on the results of a survey research studying citizens’ motivations to use e-participation platforms. More recently, Choi and Song (2020) explored the factors influencing the engagement of citizens in e-participation. We engage further in the direction of these related papers by investigating which roles citizens would be willing to take in digital government and which factors influence their preferences.

Research Model and Research Questions

The goal of the research is to determine the factors influencing the roles citizens are willing to take in digital government. Thus, at the center of our research model are **dependent variables** measuring citizens’ willingness to take on the defined roles. The factors of which we study the influence are the **independent variables**. Since there is no previous work identifying the factors impacting citizens’ willingness to take on these roles, we performed a broad search for studies published in the field of digital government with a research design similar to ours. The found studies focus on the use or intention to use of digital government services. They allowed identifying ten factors that were relevant to our research question.

For each independent variable, Table 8.5 provides the related studies it was extracted from, details the rationale behind its inclusion in this study, and maps it to a specific research question (SRQ) studying its impact on the roles citizens are willing to take in digital government. To measure them, we formulated questions about socio-demographic status, public and private e-service and social media use frequency, and digital literacy. For the digital literacy, we relied on the research instrument provided in (Hargittai, 2005; Hargittai and Hsieh, 2012; Hargittai, 2009). It consists in measuring digital literacy by asking the respondents to rate their understanding of 9 concepts on a 5-point Likert scale ranging from “No understanding” to “Full understanding.”

In order to measure the dependent variables we formulated several statements based on the literature discussed above. The statements were investigated for both the *local* and the *federal/regional* government levels to capture insights into SRQ1. Thus, for each statement, respondents had to give their opinion for their city and for their region/country. On a general note, the basis intuition was that several statements would stimulate positive answers from the respondents (S1 in particular), but the goal of this questionnaire is to analyze to which extent people agree with the statements and which factors influence the answers’ distribution. The following statements were formulated:

- S1: You wish the electronic public services of your [city|region/country] were more accessible, faster, and more integrated with other levels of authority

Table 8.5: Factors included in the research model.

Research question	Factor	Rationale
SRQ1	Level of government	The study takes place in Belgium, a country that has a multi-level governance setting (Bache et al., 2016). We therefore distinguish between the local and regional/federal levels
SRQ2a	Gender	Factor studied in (Wijnhoven et al., 2015; Rodrigues et al., 2016; Voutinioti, 2013)
SRQ2b	Age	Factor studied in (Wijnhoven et al., 2015; Voutinioti, 2013)
SRQ2c	Education	Factor studied in (Wijnhoven et al., 2015; Rodrigues et al., 2016; Voutinioti, 2013)
SRQ2d	Occupation	Factor studied in (Wijnhoven et al., 2015)
SRQ2e	Administration	We set a particular focus on *employment* in administration as public servants can have a different view toward their expected role in digital government due to their job in the administration (Baldwin et al., 2012)
SRQ3	Digital literacy	Previous research showed influence of digital literacy in the context of digital government implementations (Nawafleh, 2018)
SRQ4a SRQ4b SRQ4c	Private e-services use Social media use Public e-services use	Previous research showed a link between the use of other e-services and the use of public e-services use (Bélanger and Carter, 2009; Rodrigues et al., 2016; Voutinioti, 2013)

- S2: You would be willing to pay extra money (directly or through taxes) so that the electronic public services of your [city|region/country] are more accessible, faster, and more integrated with other levels of authority
- S3: You would take time to consult relevant information about your [city|region/country] if they were available
- S4: You would take time to use an online platform to participate in the democratic processes of your [city|region/country] if such a platform existed
- S5: In exchange for a greater time investment on your part, you would favor the use of public electronic services if it reduced your [city|region/country]'s administrative burden
- S6: You would take time to send relevant information to your [city|region/country]'s departments through an online platform if such a platform existed
- S7: You would take time to participate in the development of your [city|region/country]'s electronic public services if you were given the opportunity

S1 and S2 were derived from the Citizens as Customers role. We formulated S1 to capture the expectations related to the efficiency of the public e-services based on the vision of digital government presented in (West, 2005; Veiga et al., 2016; Eyob, 2004). Furthermore, we added S2 to check if the citizens were ready to pay for better public e-services, in a similar fashion to the freemium business model of some private e-services (Kumar, 2014).

S3 and S4 were derived from the Citizens as Participants role. S3 was added as information is an essential precondition for participation (Arnstein, 1969) and is in line with the principles of Open Government (Janssen et al., 2012). S4 was formulated around the most popular channel for e-participation in Belgium, namely the online platform (Simonofski et al., 2019b).

S5, S6, and S7 were derived from the Citizens as Coproducers role. S5 was formulated based on the proactive role that citizens can take to help governments in the execution stage (Linders, 2012). S6 was created due to the popularity of applications and platforms to help send information to government (e.g. FixMyStreet (Pak et al., 2017)). Finally, S7 captures the time citizens can take to help public agents in the development of public e-services as reported in (Simonofski et al., 2019b; Axelsson et al., 2010).

Citizens' agreement with the statements was measured using a 5-point Likert scale ranging from "Totally Disagree" to "Totally Agree." Furthermore, the statements were pre-tested with a diverse group of 10 citizens to test the understandability of the statements and the time completion.

The full questionnaire can be found in Appendix G as well as in the supplementary report associated with the publication presenting the results of this research[1].

Data Collection

We applied a multi-channel strategy for data collection in order to avoid bias induced by the lack of access to digital tools of some respondents. We put the questionnaire online, presented it through social media and on four local communities websites. Furthermore, we also printed paper versions of the questionnaire and conducted face-to-face interviews in the cities of Brussels, Namur and Charleroi (Belgium). The data collection phase lasted from June 2019 to October 2019. The completion time of the questionnaire ranged between 10 and 15 minutes per respondent with no excessive deviation from this average. This absence of outliers did not force us to remove poor quality responses from the dataset (Malhotra, 2008). The data collected is available in open access for reuse by other researchers[2].

The data collection strategy is thus based on convenience sampling (Etikan et al., 2016). Despite some limitations such as the potential lack of representativeness, convenience sampling has been applied in digital government studies in the past (Wijnhoven et al., 2015; Voutinioti, 2013; Meftah et al., 2015; Kaur and Rashid, 2008; Ahmad et al., 2013). Furthermore, we consider it sufficient given the exploratory nature of our study. As advised by Etikan et al. (2016), we compared the output of the convenience sampling with the proportions describing the general population in Belgium collected from official Belgian governmental sources. Table 8.6 shows a comparison between the sample from which we collected data and a theoretical perfectly representative sample of the Belgian population.

It can be observed from Table 8.6 that the sample suffers from representativity issues, which can be explained by the questionnaire distribution channels. Overall, younger citizens and students are overrepresented while older and retired citizens are underrepresented. While the face-to-face interviews helped mitigating this issue, the social media distribution reached mostly younger citizens (and thus, logically, students).

[1] Available at: https://zenodo.org/record/4041220#.X2iqKWgzY2w
[2] Available at: https://zenodo.org/record/4045328#.X2r3d2gzY2w

Table 8.6: Description of the surveyed sample and comparison with a theoretical sample defined by the numbers derived from official Belgian census data.

Characteristic	Sample	Population	Representativity
Gender[T1]	–	–	–
Female	92 (45.3%)	104 (51%)	–
Male	111 (54.7%)	99 (49%)	–
Age[T2]	–	–	–
<20 years	21 (10.3%)	14 (6.9%)	over
20–29 years	81 (40.0%)	30 (14.8%)	much over
30–39 years	26 (12.8%)	30 (14.8%)	–
40–49 years	30 (14.8%)	35 (17.2%)	–
50–59 years	24 (11.8%)	34 (16.7%)	under
>60 years	21 (10.3%)	60 (29.6%)	much under
Education level[T3]	–	–	–
Low	7 (3.4%)	55 (27.1%)	much under
Medium	69 (34.0%)	75 (36.9%)	–
High	127 (62.6%)	73 (36.0%)	over
Occupation[T4]	–	–	–
Employed	99 (48.8%)	93 (45.8%)	–
Self-employed	14 (6.9%)	16 (7.9%)	–
Student	67 (33.0%)	22 (10.8%)	much over
Unemployed	6 (3.0%)	9 (4.4%)	under
Homemaker	1 (0.0%)	9 (4.4%)	much under
Retired	16 (7.9%)	54 (26.6%)	much under
Total	203 (100%)	203 (100%)	–

[T1] Numbers from most recent decennial census (2011) in Belgium (available: https://www.census2011.be/data/fresult/sexratio_fr.html)
[T2] Based on the age distribution in Belgium for 2017 (available: https://statbel.fgov.be/en/themes/population/structure-population#panel-11)
[T3] The education levels reported by the Belgian government census are *low*, *medium*, and *high*. Low corresponds to an inferior secondary degree at maximum, medium to the superior secondary degree, and high to any degree higher than superior secondary (i.e. high school, university, PhD). Numbers reported by the Belgian government in 2017 can be found online: https://statbelpr.belgium.be/fr/themes/emploi-formation/formation-et-enseignement/niveau-dinstruction#figures
[T4] Based on the numbers reported by the Belgian government for 2017 (available: https://statbel.fgov.be/sites/default/files/files/documents/FR_kerncijfers_2018_web1a.pdf5 and https://statbel.fgov.be/fr/themes/emploi-formation/marche-du-travail/emploi-et-chomage#panel-12)

Data Analysis

The SRQ address the relationship between factors and agreement with statements related to the three roles defined for citizens in digital government. As agreement with these statements is measured on a 5-point Likert scale, the data collected for those is ordinal, which oriented our choice toward non-parametric statistical tests. In order to determine which statistical tests are adequate, the scale on which of the variables related to the factors are measured has to be considered. The adequate statistical tests were carefully selected from literature (Malhotra et al., 2011; Gaddis and Gaddis, 1990; Schober et al., 2018) and also from studies with a similar research design mentioned in Section 8.3.1. The SRQ involve statistical tests between ordinal variables and variables measured on several different scales. Therefore, we defined a test strategy for each scale combination as follows:

- **Dichotomous – Ordinal**: The 2-sample Kolmogorov-Smirnov (Pratt and Gibbons, 1981) test was used to compare the distribution of the dependent variable across the two groups defined by the independent variable (e.g. the distribution of answers given to S1 across males and females). If the test reveals a significant difference, visually examining the distributions allows determining the direction of the difference. This strategy was used for SRQ2a (gender) and SRQ2e (working in an administration).
- **Nominal (more than 2 groups) – Ordinal**: The Kruskal-Wallis H test (Kruskal and Wallis, 1952) was used to compare the distribution of the dependent variable across the groups defined by the independent variable (e.g. the distribution of answers given to S1 across occupation groups). If the test reveals a significant difference, a post-hoc analysis with Dunn's test (Dunn, 1961) (with Bonferroni correction) can be performed to determine if there are pairwise differences across the groups. This strategy was used for SRQ2d (occupation).
- **Ordinal – Ordinal**: The Jonckheere-Terpstra test (Jonckheere, 1954; Terpstra, 1952) was used to determine whether there is significant trend between the independent and the dependent variable (Bewick et al., 2004). An example of such trend would be that citizens with higher degrees tend to agree more with one given statement. If the test reveals a significant difference, a post-hoc analysis with Dunn's test (with Bonferroni correction) can be performed to determine if there are pairwise differences across the groups. This strategy was used for SRQ2b (age), SRQ2c (education level), SRQ4a (private e-service use frequency), SRQ4b (social media use frequency), and SRQ4c (public e-service use frequency).
- **Continuous – Ordinal**: The Jonckheere-Terpstra test was used to determine whether there is significant trend between the dependent and the independent variable. For example, the test compares the distribution of digital literacy across the five groups defined by the five possible answers to S1 to determine whether respondents agreeing more with the statement tend to have a higher or lower digital literacy. If the test reveals a significant difference, a post-hoc analysis with Dunn's test (with Bonferroni correction) was performed to determine if there are pairwise differences across the groups. The groups thus defined are labeled TD (i.e. respondents who answered "Totally disagree"), D (i.e. respondents who answered "Disagree"), N (i.e. respondents who answered "Neutral"), A (i.e. respondents who answered "Agree"), and TA (i.e. respondents who answered "Totally agree"). This strategy was used for SRQ3 (digital literacy). Indeed, a digital score could be measured for each respondent by averaging the answers given to the 9 questions on concept understanding, as Cronbach's alpha (Cronbach, 1951) is 0.923, well above the

commonly accepted threshold (Peterson, 1994). Thus, the digital literacy score is withing the range of 1 (the respondent has answered "No understanding" for the nine concepts) to 5 (the respondent has answered "Full understanding" for the nine concepts).

As for SRQ1 (government level), the answers given for the local and for the regional/federal government levels were compared pairwise, for each of the seven statements relating to the citizens' roles, in order to determine whether they tend to be similar. Spearman's rank correlation coefficient (Spearman, 1961) was used and interpreted following (Schober et al., 2018). In addition to this high-level comparison between the local and the federal/regional government levels, the finer-grained analysis of the answers to the statements in the other SRQ can also highlight differences and similarities between these two levels. All tests were conducted with the IBM SPSS v26 software.

8.3.2 Citizens' Expectations Regarding Participation in Development

In this section, we report on the significant relationships between the ten factors and the expectations of citizens we identified through our statistical analyses. A summary of the relationships is presented in Figure 8.5 and in Table 8.7. An identifier Rx is assigned to each relationship and is referred to in the text describing it. For better readability, the information related to the 25 significant relationships (i.e. statistic value and significance level) are provided in Table G.1 and G.2 in Appendix G. As they are more voluminous, the statistical details related to the post-hoc analyses as well as the visual representations of the analysis (i.e. bubble charts, box plots, and bar charts) are available in the supplementary material document. An Excel spreadsheet summarizes the 25 relationships and gives the statistical details as well[3].

Government Level (SRQ1)

Spearman's correlation coefficient was computed pairwise for each of the seven statements as detailed in Section 8.3.1. All seven coefficients have a value of 0.685 or above and are statistically significant. Following interpretation guidelines from (Schober et al., 2018) this indicates that there is a significant strong positive relationship between the answers given for the local and the federal/regional government levels. This was confirmed by visually inspecting the findings with bubble charts, which show that respondents give highly similar answers for both government levels.

Thus, no significant influence of the government level on citizens' expectations was found. However, despite the absence of macro-level influence, smaller influences were identified between several statements and factors with respect to the government level they were linked with. These are described in the following subsections.

[3]Available at: https://zenodo.org/record/4041248#.X2iqJ2gzY2w

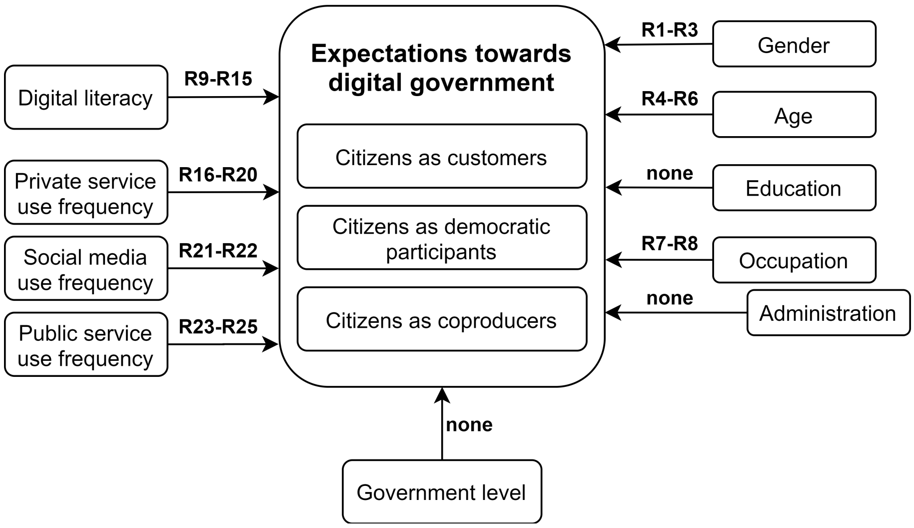


Figure 8.5: Summary of the observed relationships

Gender (SRQ2a)

The two-sample Kolmogorov-Smirnov test indicates whether the distributions of the answers to the statements differ significantly across the gender groups. However, it does not specify *how* they differ. In order to capture this information, the distributions for both gender groups were plotted on a comparative bar chart. For each statement for which a significant difference was observed, it allowed examining visually whether it is males or females who tend to agree more with the statement.

Males tend to be more in demand of faster and more integrated services (S1, **R1**) and more willing to take time to participate in the democratic processes through an online platform (S4, **R2**), for both government levels. In addition, males tend to be more willing to favor the use of public e-services to reduce the burden of the administration (S5, **R3**) for the local government level but not for the federal/regional.

Age (SRQ2b)

Citizens in the 20-29 age group tend to be more willing to pay extra money for faster and more integrated services than those in the 50-59 group, for both government levels (S2, **R4**). Also, citizens in the 20-29 age group tend to be more willing to take time to participate in the democratic processes through an online platforms than those in the 40-49 and > 60 age groups, for both government levels (S4, **R5**). Finally, citizens in the 20-29 age group tend to be more willing to favor the use of public e-services to reduce the burden of the administration for the federal/regional level, but not for the local (S5, **R6**).

Education (SRQ2c)

Our analysis showed no significant difference in the distribution of the answers across education level groups, for all seven statements.

Occupation (SRQ2d and RQ2e)

Only 1 of the respondents has the *helper* occupation, and 6 of them are *unemployed*. As these numbers are too low to study these two groups, they were sidelined from the analysis. Thus, the resulting sample holds 196 respondents divided among four occupation groups, namely *student*, *employed*, *self-employed*, and *retired*.

As for SRQ2d (occupation), there is a significant difference across occupation groups for S3 (consult information), for both government levels. As for the local level, students tend to be less willing to take time to consult relevant information than employed and self-employed citizens. The post-hoc analysis revealed no significant pairwise difference for the federal/regional level (S3, **R7**). Also, retired citizens tend to be less willing to take time to participate in the democratic processes through an online platform than students and employed citizens, for both government levels. For the local level, retired citizens are less willing to participate in the democratic processes than self-employed citizens as well (S4, **R8**).

Concerning SRQ2e (administration), 37 out of the 99 respondents in the *employed* group work in an administration. As explained in Section 8.3.1, the two compared groups are, on the one hand, citizens working in an administration, and, on the other hand, the other employed citizens. The analysis showed no significant difference in the distribution of the answers, for all seven statements.

Digital Literacy (SRQ3)

Citizens who answered TA to statement S1 (better services) tend to have a higher digital literacy than those who answered TD, N, or A, for both government levels. In addition, citizens who answered N or A tend to have a higher digital literacy than those who answered TD, for the federal/regional government level (S1, **R9**). Citizens who answered N or A to statement S2 (pay for faster services) tend to have a higher digital literacy then those who answered D, for the local level. No significant result was observed for S2 for the federal/regional level (S2, **R10**).

As for the "Citizens as Participants" role, citizens who answered TA to statement S3 (consult information) tend to have a higher digital literacy then those who answered A, for both government levels (S3, **R11**). Citizens who answered TA to statement S4 (democratic processes) tend to have a higher digital literacy then all others, for both government levels (S4, **R12**).

As for the "Citizens as Coproducers" role, there is a trend of higher digital literacy with higher agreement to statement S5 (burden), for the federal/regional government level. However, there is no significant pairwise comparison. No significant result was observed for S5 for the local level (S5, **R13**). Citizens who answered TA to statement S6 (send information) tend to have a higher digital literacy than those who answered TD, D, or A, for both government levels. In addition, citizens who answered TA tend to have a higher digital literacy than those who answered N, for the federal/regional government level (S6, **R14**). Citizens who answered TA to statement S7 (participation in development) tend to have a higher digital literacy then all others, for both government levels (S7, **R15**).

Private E-services use frequency (SRQ4a)

Citizens using private e-services daily or weekly tend to be more in demand of faster and more integrated public e-services than citizens never using them, for both government levels. In addition, citizens using private e-services daily or weekly tend to be more in demand of faster and more integrated public e-services than citizens using them yearly, for the local government level. Also, citizens using private e-services monthly tend to be more in demand of faster and more integrated public e-services than citizens never using them, for the federal/regional government level (S1, **R16**).

As for the “Citizens as Participants” role, citizens using private e-services daily tend to be more willing to take time to consult relevant information than citizens using them weekly or never using them, for both government levels. In addition, citizens using private e-services weekly or monthly tend to be more willing to take time to consult relevant information than citizens never using them, for the local government level (S3, **R17**). Citizens using private e-services daily, weekly, or monthly tend to be more willing to take time to participate in the democratic processes through an online platform than citizens never using them, for the federal/regional government level. No significant result was observed for S4 for the local level (S4, **R18**).

As for the “Citizens as Coproducers” role, citizens using private e-services daily tend to be more willing to take time to send relevant information than those never using them, for both government levels. In addition, citizens using private e-services weekly or monthly tend to be more willing to take time to send relevant information than those never using them, for the local level. Also, citizens using private e-services daily tend to be more willing to take time to send relevant information than those using them weekly, for the federal/regional level (S6, **R19**). Citizens using private e-services daily, weekly, or monthly tend to be more willing to take time to participate in the development of public e-services than citizens never using them, for both government levels (S7, **R20**).

Social Media Use Frequency (SRQ4b)

There is a trend of higher agreement to statement S1 (better e-services) with higher social media use frequency, for both government levels. However, there is no significant pairwise comparison (S1, **R21**). There is also a trend of higher agreement to statement S4 (democratic processes) with higher social media use frequency, for both government levels. The post-hoc analysis showed that citizens using social media daily tend to be more willing to take time to participate in the democratic processes through an online platform than those never using them, for the federal/regional government level. There is no significant pairwise comparison for the local level (S4, **R22**).

Public E-services Use Frequency (SRQ4c)

There is a trend of higher agreement to statement S1 (better e-services) with higher public e-service use frequency, for the federal/regional level. The post-hoc analysis showed no significant pairwise comparison. No significant result was observed for S1 for the local level (S1, **R23**). Citizens using public e-services weekly tend to be more willing to take time to participate in the democratic processes through an online platform than those using them yearly or never using them, for both government levels. In addition, citizens using public e-services daily tend to be more willing to take time to participate in the democratic processes through an online platform than those using them monthly, and citizens using public e-services monthly tend to be more willing to take time to participate in the democratic processes through an online platform than citizens never using them, for the local government level (S4, **R24**). Finally, there is a trend of higher agreement to statement S7 (participation in development) with higher public e-service use frequency, for the federal/regional level. The post-hoc analysis showed no significant pairwise comparison. No significant result was observed for S7 for the local level (S7, **R25**).

Table 8.7: Summary of the observed relationships between factors and statements

Role	Statement	SRQ1 Govern. level	SRQ2a Gender	SRQ2b Age	SRQ2c Education level	SRQ2d Occupat.	SRQ2e Working in administr.	SRQ3 Digital literacy	SRQ4a Private e-service use	SRQ4b Social media use	SRQ4c Public e-service use
Customer	S1	-	R1	–	–	–	–	R9 +*	R16 +	R21 +	R23 +
	S2	–	–	R4 -*	–	–	–	R10 +	–	–	–
Participant	S3	–	–	–	–	R7	–	R11 +	R17 +	–	–
	S4	–	R2	R5 -	–	R8	–	R12 +	R18 +	R22 +	R24 +
Coproducer	S5	–	R3	R6 -	–	–	–	R13 +	–	–	–
	S6	–	–	–	–	–	–	R14 +	R19 +	–	–
	S7	–	–	–	–	–	–	R15 +	R20 +	–	R25 +

S1–Demand for faster and more integrated public e-services
S2–Willingness to pay extra money for faster and more integrated public e-services
S3–Willingness to take time to consult relevant information
S4–Willingness to take time to participate in the democratic processes through an online platform
S5–Willingness to favor the use of public e-services if it reduces government's administrative burden
S6–Willingness to take time to send relevant information
S7–Willingness to take time to participate in the development of public e-services

*** -** – Respondents with **lower** values of the independent variable (factor) tend to have higher values for the dependent variable (statement)
+ – Respondents with **higher** values of the independent variable (factor) tend to have higher values for the dependent variable (statement)

8.3.3 Recommendations for Public Display Design

Once the expectations for a given population are identified, a logical next step would be to translate them into concrete participation actions better suited to the target population's specifics. We here suggest some leads for several relationships we identified from our analyses:

- In **R2**, we found out that males were more willing to take time to participate in the online democratic processes. This is consistent with the gender gap identified by Vicente and Novo (2014) in the context of e-participation. One solution could be to organize offline sessions dedicated to women or to collect requirements from them to understand why they are less willing to participate in the democratic processes, and thus adapt online democratic process accordingly. The same reasoning applies for the discrepancies in age groups from **R5**.
- In **R9-R15**, we found out that the fragment of the population with higher digital literacy had higher expectations toward digital government. Indeed, in order to get deeper insights into the expectations of the respondents having a lower digital literacy, we conducted an analysis focused on the 36 having a digital literacy score of 2/5 or less. Overall, they are in demand of faster and more integrated public e-services and they are willing to use such services to consult information, to participate in democratic processes, and to send information. However, they are not willing to pay extra money for this. Regarding the willingness to contribute to reducing the government's administrative load, there is no clear tendency. Finally, approximately 25% of the 36 respondents are willing to participation in the development of these services, compared to 61% for the other respondents. These findings are alike for the local and the federal/regional government level. The respondents with lower reported digital literacy would thus be more difficult to mobilize to participate in the development of digital government services. Therefore, in order to ensure a representative requirements elicitation when designing a public display, proactive actions should be implemented to collect the input of citizens with lower digital literacy in an inclusive manner to ensure that the public display is aligned with their needs. The use of focus groups and crowd-centric requirements engineering platforms to crowdsource the requirements engineering task in a user-friendly manner, using gamification for instance, would constitute way forwards to achieve this (Snijders et al., 2015). Regarding citizens with a higher digital literacy we would suggest to consider them as lead users (Von Hippel, 1986) and to include them in reflections related to digital transformation.
- In **R19**, we found out that citizens who use private e-services more frequently were more willing to send information to their government via a dedicated application. As the boundary between private and public e-services is becoming less distinct (Lindgren and Jansson, 2013), a policy-maker could identify the features of private e-services that drive the citizens to use them and incorporate them into the developed application.

- In **R20** and **R25**, we found that citizens using private and public e-services use more frequently are more willing to participate in the development of public e-services. We have not observed the same trend for social media. Therefore, we recommend to disseminate the calls for participation in public display development through other services than social media. Complementarily, citizens not using e-services frequently should be reached through means not relying on technology such as mail or paper posters.

8.4 A Process Model for Public Display Adaptation

While many motivators encourage citizens to interact with public displays for participation, many deterrents dissuade them to use such systems. As discussed in the lead "Handling a Changing Context" from the research agenda, adaptive public displays could increase the interactions in such citizen engagement by strengthening these motivators and lowering these deterrents. In order to help the designers to conceive such adaptive public displays, we elaborated a process model serving as system design support tool.

We describe the methodology followed to create this process model in Section 8.4.1. The process model is presented and illustrated with the case of a voting system in Section 8.4.2

8.4.1 Methodology

The empirical contributions presenting public displays supporting citizen participation surveyed in Section 8.2 have reported on the motivators (resp. deterrents) encouraging (resp. deterring) users to interact with their systems. These serve as foundation for the process model we propose. Its goal is to improve the citizen participation experience by leveraging adaptation to strengthen motivators and lower deterrents.

In total, out of the 34 surveyed articles, 27 report on motivators and/or deterrents to interaction. We only noted the factors that are reported sometimes as a motivator and sometimes as a deterrent in the literature. Factors impacting interaction solely as motivator (e.g. honeypot effect, playfulness) or as deterrent (e.g. display blindness, interaction blindness) were set aside for these papers, as they inform general design recommendations rather than opportunities for adaptation. 20 articles report on motivators and deterrents relevant for adaptation. Table 8.8 lists the factors impacting interaction along with the articles reporting them as motivator, deterrent, or both.

8.4.2 Process Model

Figure 8.6 depicts the process model defined to help designers in the creation of adaptive public displays. This model is composed of five steps, each dedicated to one of the five big W questions (**W**hy, **W**ho, **W**hen, ho**W** and **W**hat). Starting from an interest of adaptation in the intention to increase the motivators and/or decrease

Table 8.8: Factors impacting interaction as motivator, deterrent, or both in the surveyed articles.

Factor	Motivator	Deterrent	Both
Technology	(Schiavo et al., 2013b; Hespanhol et al., 2015; Koeman et al., 2015; Steinberger et al., 2014; Fortin et al., 2014a; Fredericks et al., 2015)	(Hosio et al., 2014a, 2015; Whittle et al., 2010)	(Schroeter, 2012)
Social exposure	(Schroeter, 2012; Steinberger et al., 2014)	(Claes et al., 2017; Baldauf et al., 2014; Valkanova et al., 2014; Hespanhol et al., 2015; Hosio et al., 2014a)	–
Time available	(Baldauf et al., 2014; Steinberger et al., 2014; Schroeter and Houghton, 2011)	(Schroeter, 2012; Coenen et al., 2019b)	–
Topic interest	(Koeman et al., 2015; Schroeter and Houghton, 2011)	(Schroeter, 2012)	(Schiavo et al., 2013b; Steinberger et al., 2014; Claes et al., 2016)
Content from others	(Schroeter, 2012; Valkanova et al., 2014; Hosio et al., 2015)	(Schroeter and Houghton, 2011)	–
Feedback form	(Hosio et al., 2014a)	(Schroeter, 2012)	–
Content presentation	(Taylor et al., 2012; Koeman et al., 2015)	–	(Mahyar et al., 2016; Claes et al., 2018)
Perceived impact	(Coenen et al., 2019b)	(Schiavo et al., 2013b; Noyman et al., 2017)	(Taylor et al., 2012)

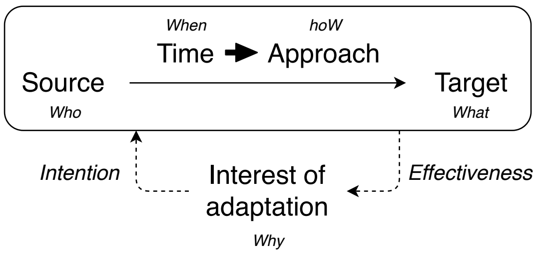


Figure 8.6: Process model destined to help the designers in the creation of adaptive public displays.

the deterrents, the designer defines the source, the time, the approach based on the time, and the target of the adaptation. Furthermore, with this process model, the designer can assess the impact of the adaptation in a field setting by measuring the difference between the effective and the intended effect on motivators/deterrents to confirm or not the interest of adaptation. Each of these steps are described and exemplified below with the case of a voting system, and illustrated in Figure 8.7.

Interest of adaptation The designer first thinks about **why** an adaptation can strengthen the motivators or lower the deterrents to citizen participation. In our voting case study, the main objective is to increase the participation of the voters. For that, the designer considers a way to gather feedback from citizens having less

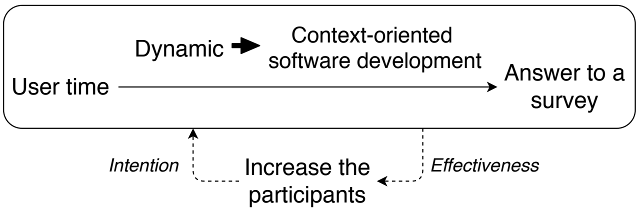


Figure 8.7: An instance of the process model where the adaptation proposes different ways to answer a survey depending on the time availability of the users to increase the number of participants.

time available.

Source After considering why an adaptation is interesting, the designer defines **who** causes the adaptation. In adaptive systems, the perception of the environment leads to an adaptation to refine the behavior of the system (de Lemos et al., 2009). For example, in context-aware systems (i.e. a specific field of adaptive systems), this environment can be defined by the users (e.g. the time they have), by external information (e.g. the weather), and by physical information (e.g. the size of the screen) (Coutaz et al., 2005; Mens et al., 2016). Based on this definition of the environment, the form of feedback sought from citizens can be differ according to their time available.

Target The designer also defines **what**/which features can be adapted according to the environment in which the system runs. For instance, the feature proposing to send a feedback can be adapted according to the surrounding environment. If a citizen has little time available or if it is raining, giving feedback could consist in choosing from a range of predefined answers. Otherwise, a richer plain-text feedback could be sent. The modality to send a feedback can also vary. Depending on the citizens' preferences, they could send their feedback from an external device preserving privacy or by touching the screen to answer the question in a less private way.

Time The designer considers **when** the adaptation must occur. The adaptation can either be static or dynamic. While a static adaptation is planned entirely by the developer, a dynamic adaptation is planned at runtime for which some behaviors can be refined depending on the surrounding environment in which they run (McKinley et al., 2004). Even though we mention static time, we only focus on dynamic time in this paper as our scope is adaptive public displays.

Approach Finally, the designers defines **how** the adaptation will occur, in terms of technology. Static approaches as well as an extensive coverage of the existing approaches are out of the scope of this paper. Some dynamic adaptation approaches are briefly discussed. A first approach is based on model-driven engineering approaches although their solutions are mainly devoted to the user interface adaptation, by relying either on the Cameleon Reference Framework (Calvary et al., 2003) (e.g. UsiXML (Tesoriero and Vanderdonckt, 2010; Limbourg et al., 2004)), or on their own architecture such as the three-layered CAUCE architecture (Tesoriero et al., 2010), or COMET(s), a software architectural style and interactors toolkit for plastic user interfaces (Demeure et al., 2008). Other approaches dealing with the software engineering aspects of dynamic adaptation exist such as context-oriented programming (Hirschfeld et al., 2008; Ghezzi et al., 2010; Aotani et al., 2011; González et al., 2011; Salvaneschi et al., 2012; González et al., 2013; Duhoux et al., 2019).

8.4.3 Challenges to Adaptive Public Displays

Although there is potential for adaptive public displays supporting citizen participation, the development of such interfaces is fraught with challenges that would be fair to acknowledge.

First, building an adaptive public display is clearly a more complex task for developers than developing a traditional one. However, the software engineering literature has proposed programming approaches as discussed previously and development tools (e.g. (Duhoux et al., 2018)) to support developers in this regard. The development of adaptive public displays also requires sensors, which induce additional hardware equipment expenses, thus increasing the already high cost (Hosio et al., 2014b) of public displays. In the context of citizen participation, such displays are often deployed by local governments, who might be reluctant to deploy costly systems.

Second, one issue that is likely to emerge at some point in the deployment of an adaptive public displays is conflicting contexts. For instance, if the display adapts the content presentation to the age of its user, a conflict can emerge when several users of different ages are using the display simultaneously. Previous works have proposed techniques for handling conflicting contexts and are surveyed in (Mens et al., 2017).

Third, Kurdyukova (2011) reported that adaptive public displays are likely to lose users' trust if they lack transparency and controllability in their behavior. This issue is critical in the context of citizen participation. Indeed, several studies surveyed in (Alzahrani et al., 2017) noted that the trust in the technology has an important impact on citizen's trust in electronic government (e-government) and on the intention to use e-government systems. Also, Tolbert and Mossberger (2006) have shown that "increased government trust is produced by improved interactions through e-government." Therefore, mistrust in the adaptive public display would have a heavily detrimental impact on not only the public display use, but also on the efforts toward e-government in general. This calls for careful consideration of user evaluations in adaptive public displays research in order to ensure that they are trusted and accepted by the public.

Fourth, previous literature has highlighted the challenges pertaining to the evaluation of public displays (Alt et al., 2012; Hornecker and Nicol, 2012). Indeed, whereas laboratory studies are able to predict usability issues, factors related to the environment require a more costly field evaluation to be studied (Hornecker and Nicol, 2012). In the case of adaptive public displays, dynamic events have to occur in order for the behavior of the display to be evaluated. Nonetheless, a promising avenue in this regard is controlled in-the-wild evaluation (Claes et al., 2015) which allows simulating such events in a field setting, thus preserving ecological validity.

8.5 Limitations

This section presents the limitations of the research results presented in this chapter.

The first set of limitations concerns the planning and conduct of the literature review. We briefly discuss five limitations related to the search terms, the search fields, the selected digital libraries, the application of inclusion and exclusion criteria, and the categorization process. We explain their impact on the validity of the literature review and how we mitigated them.

Search terms Following the PICOC framework described by Petticrew and Roberts (2006), a group of keywords including **display** and synonyms, another group composed of **public** and synonyms and another containing terms related to **participation** have been combined. Still, other keywords could have been added to the search query. This would have increased the number of yielded articles and consequently the representativity of the surveyed sample. Nonetheless, the defined set of keywords results from a previous systematic literature review and explorations of the field and was refined throughout the review by including keywords from related domains such as media architecture. Thus, it should be representative enough for the purposes of the survey.

Search fields The search was performed on the title and on the keywords fields only. Thus, relevant articles could have been missed out. However, the defined search query is not too restrictive to be performed on these fields. One can indeed reasonably expect to find one keyword from each group in the title or in the keywords of an article on the use of public displays for citizen participation. Conducting the search on the abstract field was considered early in the study but this option was ruled out. Keeping the keywords as-is, the number of articles returned is unmanageable (more than 5,000 for the ACM Digital Library only).

Selected digital libraries The initial search was restricted to three digital libraries. Other digital libraries such as Scopus were considered, but they were sidelined to keep a manageable number of articles to review. However, the selected digital libraries cover both conferences and journals, which are the main channels to publish research on public displays and citizen participation. Also, a bidirectional snowball analysis was performed on a previous literature review by Du et al. (2017) to extend the coverage. The bibliographies of all selected articles were carefully checked for additional relevant work, which references were perused as well. As a final check of coverage completeness, the keyword search was performed on Google Scholar. The search yielded no relevant work that was not previously captured. Thus, the search has most likely captured a fair part of the existing articles.

Application of Criteria The relevance of the articles yielded by the search and the snowball analysis was assessed based on the abstract only. Supposedly, the abstract contains the information needed for this decision, but it could happen that relevant articles were missed out in the process.

Categorization The surveyed papers were categorized based on the researchers' understanding after reading them. Since the authors of the surveyed papers were not involved in the review process, the study is not immune to misinterpretations. However, this limitation was mitigated by having at least two researchers reading each paper and discussing their understanding. Few divergences emerged, as the classification scheme was for the most part derived from literature which provided guidelines for classifying the information extracted from the papers. All divergences between the researchers could be solved by discussing and reaching an agreement.

The second set of limitations concerns the survey research on expectations toward digital government. It comprises three limitations, relating to the taxonomy chosen to describe the roles of citizens in digital government, the set of factors which influence was studied, and the representativity of the sample. For each, we describe the impact on the findings as well as the future research directions they open

Roles taxonomy stems from the three roles and the derived set of statements we used to develop the elicit the expectations from citizens. Other frameworks that structure the roles of citizens in digital government exist. For instance, the typology from (Distel and Lindgren, 2019) structures the citizens into six user types: minimal user, power user, communicative user, pragmatic user, goal-oriented occasional user, and versatile occasional user. The structure of the questionnaire and the questions about the expectations could have been adapted according to such a typology. This could have led to different findings and therefore other recommendations. It would be interesting to devise another questionnaire based on a different citizen typology such as (Distel and Lindgren, 2019) to determine to which extent the findings are similar, complementary, or contradictory with ours.

Set of factors Due to the exploratory nature of this work, we examined the influence of several factors we selected from related literature on expectations but other factors could have been studied as well, such as the perceived quality of public services for instance. However, including additional factors in this study would have made our questionnaire longer to complete and potentially decreased the quality of the collected responses (Malhotra, 2008), which could have deterred some citizens from answering. Therefore, we limited our study to ten factors and left the others for future research. In Chapter 10 we provide research leads to undertake research in this direction.

Representativity The study was performed on a sample of citizens in Belgium. As shown in Table 8.6, the sample overall matches the distribution of the Belgian population. However, despite the efforts we undertook to alleviate this issue, such as targeted administering to collect more data from underrepresented groups, it still differs from the theoretical perfectly representative sample in several ways. Thus, further research is needed to ensure generalization of the findings to the rest of the Belgian population, let alone the population outside Belgium, through a large scale validation study. Despite the local character of this study, it still delivers relevant implications for research and practice.

The third set of limitations concerns the process model for adaptive public displays developers. As for the two other sets, their impact on the findings is briefly discussed below.

Extracted motivators and deterrents The process model was developed from the deterrents and motivators extracted during the literature review. Therefore, it is also impacted by the first set of limitations discussed in this section.

Validation The process model was peer-reviewed but remains a work in progress contribution in the sense that it was not validated with its target audience, that is, public display developers. Further research is needed to remedy this issue by determining whether the process model constitutes the support expected by developers and, if not, how it can be improved.

On a more general note, whereas the objective of Chapter 6 and Chapter 7 is to provide directly reusable resources for teachers and OGD portal developers / OGD publishers respectively, the goal of this chapter is more exploratory and is to give a snapshot of the existing and to open perspectives. This is the reason why its focused contributions sought to pave the way toward new contributions. Indeed, the analysis of citizens' expectations is a first step toward providing detailed recommendations regarding public display design and the adaptation process model is still in the state of work-in-progress.

8.6 Conclusion

Earlier in this thesis, we explained that the participation methods most implemented in practice have an entry deterrent, which can hinder their accessibility. We made a case for public displays as candidate method to alleviate this issue since its peculiarities makes it able to attract much more participating citizens. However, public displays are still rarely used for citizen participation purposes. The goal of this chapter was therefore to propose leads to expand the adoption of the public display in this context. This goal was pursued by building multiple contributions.

As a first step forward, we conducted a literature review of public displays and citizen participation. It studies two perspectives, namely the usage of public displays to support citizen participation and the involvement of citizens in the development (including the evaluation) of the display. It shows the current trends in the use of public displays as participation method

From the findings of the literature review, a research agenda comprising four leads for expanding the adoption of public displays. The leads are (1) involving end-users early in the development to better capture their requirements and encourage their acceptance of the display, (2) revisit the usual public display setup to accommodate other forms of participation, and therefore expand the possible uses of the public display, (3) integrate the public display with the other existing participation methods to harness their complementarity, and (4) introduce interface adaptation in public displays to cater for changes in users and environment and in turn provide a more appropriate participation experience.

Lead (1) was dug deeper through a survey on citizens' expectations that delves deeper into the involvement of citizens in the development of public electronic services that allowed identifying 26 significant relationships between citizens' characteristics, and citizens' expectations. More precisely, we have identified relationships between expectations and government level, gender, age, occupation, use frequency of other e-services, and digital literacy. The main factors impacting the roles citizens are willing to take are the digital literacy (7 relationships) and the private e-service use (5 relationships)

Lead (4) was studied deeper as well through the elaboration of a process model for adaptive public displays. It allows developers to model adaptation features in public displays . As next step, a validation of our proposal is necessary to evaluate the efficiency of the process model as a guide for designers.

Part IV

Discussion and Concluding Remarks

CHAPTER 9

DISCUSSION

This chapter summarizes the contributions of this thesis and discusses their implication for both practice and research. On the research side (Section 9.1), the contributions are mapped to the research questions formulated in Chapter 4 and we explain the extent to which these questions find an answer in the contributions. On the practice side (Section 9.2), the impact of the contributions is discussed for each concerned party. Finally, the limitations of this thesis are addressed in Section 9.3.

9.1 Implications for Research

The work presented in this thesis addresses three research gaps that were identified in the literature review presented in Chapter 2. These gaps were mapped to the three research questions listed in Chapter 4. We recall them below.

Research Question 1: How to educate children to the participatory smart city in a school setting?
Research Question 2: To what extent do current OGD portals meet citizens' requirements?
Research Question 3: What citizen participation purposes can public displays efficiently serve?

Overall, eleven contributions are presented in this thesis. They are briefly summarized below.

The first contribution is the **conduct** (1) of the participatory smart city introduction workshop and its different formats allowing to accommodate various in-class contexts. The workshop underwent an extensive **validation** that allow collecting data on its impact as well as on its positive and negative points (2). These insights served as foundation for the development of the **tangible interaction table** (3), which is the third contribution of this thesis.

Then, the analysis of citizens' requirements toward OGD portals allowed constituting a **list of 26 requirements** (4). The requirements of expert citizens were refined by a study of impediments faced in a larger-scale OGD use project. This resulted in the identification of **7 impediments** that make the use of OGD difficult for expert users (5). Starting from a demand for visualizations on OGD portals that is shared by expert and lay citizens, a **visualization guide** (6) was developed to help developers to choose the most appropriate visual representations for intra-city traffic data. Finally, building on these three contributions, **4 recommendations** (7) were formulated toward OGD portal developers and OGD publishers.

Lastly, previous works on public displays and citizen participation were collected and analyzed to give a complete picture and open perspectives. This work had a dual output, namely a **literature review** (8) presenting the current trends and gaps in research on public displays and citizen participation, as well as a **research agenda** (9) proposing 4 research directions to pursue in order to expand the adoption of public displays as a participation method. Delving deeper into one of these directions (Lead (1)), we studied the expectations of citizens regarding their involvement in the development of public e-services. We were able to identify **26 relationships** between influencing factors and citizens' expectations (10). Another direction (Lead (4)) was pursued as well and led to the development of a **process model** (11) destined to support designers in the development of adaptive public displays.

Each of the research outputs of this thesis contributes to one of its three research questions and to one or more research sub-sections. The mapping between the contributions and the research sub-questions is presented in Table 9.1. In the following paragraph, we further detail this mapping and we discuss the extent to which the three research questions find an answer in the 11 contributions.

Table 9.1: Mapping between the thesis contributions and the research sub-questions.

	Workshop			OGD portals				Public displays			
Research question	**Conduct**	**Validation**	**Tangible table**	**Requirements**	**Impediments**	**Visualization guide**	**Recommen-dations**	**Literature review**	**Research agenda**	**Citizens' expectations**	**Process model**
RQ1a: What elements do children consider as important in an introduction to the participatory smart city?		X									
RQ1b: How to educate children to the participatory smart city in a way that fits the school setting constraints and that incorporates the elements important to them?	X		X								
RQ2a: What are citizens' requirements toward OGD portals?				X	X						
RQ2b: How can current OGD portals be improved to better meet citizens' requirements?						X	X				
RQ3a: How can citizens be involved in the development of public displays?								X	X	X	
RQ3b: How can public displays be used as participation method?								X	X		X

Regarding Research Question 1, we developed a workshop aiming at introducing the concept to 12-14-year old children. We have devised several formats to accommodate for a wide range of constraints related to the in-school setting. The workshop conduct therefore contributes to RQ1b, by showing that it is possible to develop an activity fitting the constraints of the school environment that can change 12-14-year old children's understanding of the participatory smart city. The positive and negative points of the workshop raised by children in the evaluation allowed identifying the elements children find desirable in such a workshop, therefore answering RQ1a. This evaluation led to the design of a second version of the workshop, supported by a tangible interaction table, which constitutes an additional contribution to RQ1b. Indeed, it is an improvement of the 2x100 format that incorporates the elements identified by children for RQ1a.

Concerning Research Question 2, we have identified 26 requirements toward OGD portals by conducting interviews with both lay and expert citizens. The requirements of expert citizens were refined by analyzing the impediments 30 experts faced in a full-scale OGD use project. These two contributions, namely the detailed list of requirements and of experts' impediments, provide a direct answer to RQ2a. The requirements analysis showed that a major common ground between lay citizens and experts is the demand for visualizations on OGD portals. We dug deeper into this requirement and developed a guide destined to help portal developers to choose the most appropriate visualization techniques to feature on the portal. The guide is focused on intra-city mobility data due to the popularity of this theme in citizen participation processes. This visualization guide addresses RQ2b and constitutes the third contribution of this chapter. The analysis of requirements, impediments, and the visualization guide allowed formulating four recommendations for OGD publishers and portal developers. They constitute a contribution to RQ2b as well.

The first part of RQ2 finds a rather complete answer with the identification of requirements and impediments, as suggested by the saturation of findings we observed in the requirements elicitation. However, in order to provide a more solid answer to this question, different OGD portals should be confronted to citizens as well, and other types of OGD use projects (i.e. outside the educational context, projects conducted by lay citizens) should be investigated as well. As for the second part of RQ2, the visualization guide and recommendations do provide elements of answer but in no way constitute a full-fledged answer. Additional recommendations should be derived from additional research on RQ2a and solutions to all the requirements should be investigated and evaluated.

Regarding Research Question 3 ("What citizen participation purposes can public displays efficiently serve?"), the first contribution is a literature review of public displays and citizen participation. It studies two perspectives of public displays and citizen participation, namely the usage of public displays to support citizen participation and the involvement of citizens in the development (including the evaluation) of the display. It contributes to both RQ3a and RQ3b by describing how previous works answer these questions. From the findings of the literature review, a research agenda comprising four leads for expanding the adoption of public displays. The leads are (1) involving end-users early in the development to better capture their requirements and encourage their acceptance of the display, (2) revisit the usual public display setup to accommodate other forms of participation, and therefore expand the possible uses of the public display, (3) integrate the public display with the other existing participation methods to harness their complementarity, and (4) introduce interface adaptation in public displays to cater for changes in users and environment and in turn provide a more appropriate participation experience. The research agenda thus constitutes another contribution to both RQ3a and RQ3b. Lead (1) was dug deeper through a survey on citizens' expectations delves that deeper into the involvement of citizens in the development of public electronic services that allowed identifying 26 significant relationships between factors (i.e. socio-demographic characteristics, digital literacy, and e-service use), and citizens' expectations. It therefore provides another new contribution to RQ3a. Lead (4) was studied deeper as well through the elaboration of a process model for adaptive public displays that brings new insights on how public displays can be used to support citizen participation by catering to various changes in the participation context. It is thus another contribution to RQ3b.

The four contributions discussed above provide elements of answer to RQ3. The literature review identified when and how citizens are involved in the development of public displays in the current literature, and the analysis of expectations delivered insights and recommendations on the preferences of citizens for this type of involvement. To strengthen this contribution to research, it would be interesting to operationalize these expectations in the development of public displays and to observe the level of engagement of citizens. Concerning the second part of RQ3, the literature review has described the current usages of public displays for citizen participation, and the process model supports the development of a specific type of public display. However, a more complete answer to RQ3b would require investigating usages of public displays that go beyond those reported in the literature. Furthermore, the process model was not validated with developers, the extent of its contribution to RQ3b remains to be determined.

More generally, as contribution toward other research, the work presented in this thesis was disseminated through peer-reviewed publications, posters, and conference presentations. In addition, all the data collection instruments (i.e. questionnaires and interview guides) are provided in full in the appendix. The information extracted from the articles surveyed in the two systematic literature reviews are included in this manuscript as well, and the questionnaire data from the analysis of citizens' expectations toward e-government is published in free access as well. All this constitute a basis to support the work of other researchers.

9.2 Implications for Practice

In addition to the research gaps, the research questions this thesis addresses were also derived from three challenges for practice were identified from a study of the Walloon smart city context in Chapter 3. They are recalled below.

Challenge for Practice 1: Need to provide new and tested participation methods that can complement existing ones and compensate for their inherent limitations.
Challenge for Practice 2: Need to determine whether current OGD portals are adapted to citizens' needs, and, if appropriate, to provide leads for improvement in order to increase their use.
Challenge for Practice 3: Need for tools assisting primary and secondary teachers in critically discussing technology and citizen participation in their classrooms.

Regarding Challenge for Practice 1, the literature review constitutes a set of "success stories" of public displays used for participation. It is useful for public servants interested to offer citizen participation through public displays to draw inspiration from cases similar to their. Furthermore, the findings and recommendations from the analysis of citizens' expectations toward e-government are useful for guide public servants in choosing how to involve citizens in the development of the public displays they would put in place. Furthermore, public servants can reuse the questionnaire and distribute it to better understand their population and adapt the digitalization of government accordingly. Depending on the distribution of the expectations, the policy-makers can adapt the digital government strategy so that it is customer-oriented, participation-oriented, or coproducer-oriented. Finally, the process model for adaptive public displays helps public display developers to model adaptation features in a simple way. However, as mentioned earlier, the process model is a work in progress that was not validated with developers, and the extent of its contribution to practice has yet to be fully assessed.

As for Challenge for Practice 2, the analysis of requirements and of impediments as well as the recommendations provided in terms of mobility visualization and interface design have a direct impact on OGD publishers and portal developers. Contacts with several OGD publishers during this thesis rapidly showed that their biggest challenge is to attract users on their portal. The interest of publishers for solutions in this regard was for example confirmed with the OGD use project from which the impediments were derived, in which the OGD publisher from Namur was directly involved. Portal developers also have a direct interest in the complete list of requirements provided in this thesis, as it can help them provide more adapted solutions to their customers. Furthermore, the analysis of requirements and impediments was mainly based on the OGD portal of Namur, which is developed by OpenDataSoft. OpenDataSoft is a market leader in the provision of OGD portals in Belgium, many publishers have acquired their solution. Since the analysis of requirements and impediments was mainly based on the OGD portal of Namur, which is developed by OpenDataSoft, our findings are easily transferable to numerous OGD publishers in Belgium.

Finally, regarding Challenge for Practice 3, the workshop conduct offers a direct support for teachers to discuss technology and democracy in their classrooms, while taking their timing constraints into account. The workshop was extensively validated and can therefore be reproduced as-is using the descriptions provided in this thesis and the material available on the School-IT website[1]. Another version of

[1] https://school-it.info.unamur.be/smart-city/

the workshop, supported by a tangible interaction table, has been developed. We are currently working the TRAKK living lab to refine its design before conducting evaluations. The workshop also had an impact on 299 children from several cities across Wallonia. For the large majority, it was the first time they encountered the smart city concept. Judging from the results of the workshop and the enthusiasm of the children we observed during the sessions, the workshop was successful in introducing the concept to them in an enjoyable way.

9.3 General Limitations

This section presents four limitations of the research reported in this thesis. The limitations discussed earlier in Chapters 6, 7, and 8 are specific to one contribution and mainly consist in threats to validity affecting data collection, analysis, and evaluation. Rather, the limitations presented in this section go up one level of abstraction and are pertaining to the global approach undertook to address the central research question of this thesis.

Alternative Research Designs The first limitation concerns the overall research approach. The objective of this thesis is making citizen more accessible by alleviating its barriers. The approach chosen was heavily influenced by the research context and the timing constraints it imposes (i.e. completing the thesis in 4 years within a research project) and consists in addressing three citizen-oriented barriers. The chosen approach could have differed in several ways.

- **Focus on other barriers**: The barriers were selected from a literature review and an analysis of the practical context of Wallonia with the goal to contribute to both research and practice. However, as discussed in Section 2.3, other barriers could have been investigated, such as consultation fatigue (i.e. how to articulate citizen participation activities in order to maintain the interest of citizens in participation) and the trust of citizens in government (i.e. how to engage citizens in participation in a context where the trust between citizens and their representatives in on the decrease (Armingeon and Guthmann, 2014)?).
- **Focus on more barriers**: These barriers as well as others could have been included in the scope of this thesis in order to address the main research question in a more holistic way. However, this would have limited the research effort allocated, and in turn the volume of contribution, for each individual barrier. This approach favors breadth over depth.
- **Focus on less barriers**: As explained in Section 9.1, the contributions of this thesis are limited to elements of answer for some of the research questions. Another approach could therefore be to focus on a more restricted set of barriers, or even only one, to be more thorough on the validation of its contribution and to allow several rounds of iteration. If only Barrier 1 was investigated in this thesis, all the formats of the workshop could have been more extensively validated, and several iterations of the workshop could have been developed and tested as well. If the core of the thesis was Barrier 2, a novel OGD portal

implementing the findings of the contributions could have been developed and tested iteratively. If the thesis had focused only on Barrier 3, prototypes of public displays could have been developed and tested to explore the directions from the research agenda. Overall, the contribution to research and practice would be optimized in terms of knowledge and artifacts usable by practitioners, but very few barriers could be investigated. This approach favors depth over breadth.

The approach chosen in this thesis is a compromise between breadth and depth. It allowed addressing several research gaps and challenges for practice while delivering contributions directly usable by researchers and practitioners. This approach mitigates both the depth and breadth limitation. However, it still suffers from both to some extent.

Barriers Investigated Independently The second limitation is also related to general research design of this thesis. It is that the three barriers have been investigated independently. Although some connections have been addressed (e.g. the inclusiveness of citizen participation methods, which is the focus of Barrier 3, was discussed during the workshop sessions), no contribution addresses more than one research question. This left out several relationships between the barriers and contributions that would have been valuable to explore to contribute to the main research question. For example, transition between Barrier 1 and Barrier 2 could have been studied by incorporating data literacy (i.e. data literacy is defined by Deahl (2014) as "the ability to understand, find, collect, interpret, visualize, and support arguments using quantitative and qualitative data") into the workshop, or in a separate dedicated workshop. Indeed, since citizen participation involves data, data literacy could be viewed as a necessary first step on the same level as introducing the participatory smart city concept. Several approaches to teach data literacy schools have been proposed and are surveyed in (Wolff et al., 2016). Further research could study how they could be incorporated with the workshop. Similarly, the transition between Barrier 2 and Barrier 3 was left out. Barrier 2 states that data needed for participation, and Barrier 3 suggests to use public displays as participation method. However, the role of public displays regarding data (i.e. should a public display present the data relevant to participation, or should citizens have knowledge of this data before interacting with the display) has not been investigated in this thesis. It would be interesting to research how this role changes according to e.g. the level and topic of participation the public display serves, especially if the display is adaptive.

Data Collected from Citizens Only A third limitation is that data was collected only from citizens and literature in this thesis. Indeed, the general approach to several contributions was to conduct interviews or distribute questionnaires to collect opinions and expectations directly from citizens, which in turn were analyzed to formulate recommendations on e.g. the design of OGD portals and the involvement of citizens in the development of public electronic services. On the other hand, the visualization guide and the process model describing adaptive public displays were developed solely from literature reviews. However, whereas these contributions are directly addressed to teachers, public agents, and developers, they were not validated with them. First, regarding the resources provided to teachers on the workshop, they have been developed in collaboration with the education experts from the School-IT research project[2] who have experience in developing similar support resources for teachers. Nonetheless, it would have been interesting to interview teachers to determine whether they consider them a sufficient support to animate the workshop on their own. Another approach for validation, though more difficult to conduct, would be to analyze the results of workshop sessions animated by the teacher with the provided resources as sole basis. Second, the process model was developed in collaboration with a researcher who has experience in building modeling tools for developers of adaptive systems. Finally, regarding the recommendations formulated toward public servants, and especially those on the involvement of citizens in public electronic services development, it would have been interesting to conduct follow-up interviews with public servants to discuss the recommendations in terms of actionability. A stratified sampling of public servants based e.g. on the level of government and on other influencing factors such as public values (Simonofski et al., 2020b) could be performed in order to select a representative set of public servants for these interviews. The comparison of the findings across different public servants would allow refining the recommendations by proposing several alternatives lines of action to implement them.

Data Collection Based in Belgium Only Fourth, data was collected from Belgian citizens only. Thus, findings could suffer generalization issues if transposed to another country. This poses no issue to the contributions for practice since they are meant to be specific to the Belgian, and even the Walloon context. However, this is more problematic for the contributions to research. It would be interesting to compare the findings obtained in this study with findings from international researchers. Such an international comparison would be useful, and needed, since some efforts related to participation go beyond the national level. For instance, there is a European open data portal[3] and citizen participation is implemented on the European level[4] as well. These are destined to citizens across multiple countries, and could therefore benefit from a data collection on e.g. requirements and expectations on an international scale. All the data collection instruments used in this thesis are provided in full in the appendices and can constitute a starting point for this process. The instruments could be refined to include additional factors, such as the impact of national culture (Hofstede, 1991), that would explain potential differences across countries.

[2] https://school-it.info.unamur.be/
[3] https://data.europa.eu/en
[4] https://europeanmovement.eu/emi-enhancing-citizen-participation-in-the-european-union/

CHAPTER 10

FUTURE WORK

The limitations discussed in Chapter 9 paved the way for several future work directions involving additional data collection and validation of the contributions for the main part. In this chapter, we present four additional leads for further research that do not stem from the limitations. They propose new contributions for which the research presented in this thesis can serve as basis.

10.1 Expand the Workshop to Adult Participation

The workshop introduces the smart city to children and enables their participation within this paradigm. However, children are only a sub-group of the citizenry and the extension of the workshop to adults is a promising lead for further research. Indeed, throughout the workshop presentations that were given to practitioners, a recurring insight was that the target audience could beyond the children and reach adults as well. One challenge that should nonetheless be acknowledged is the recruiting of participants. All the workshop sessions we organized took the form of an in-class activity, thus not raising any participant recruiting issue as the activity was mandatory to attend for the children. However, as mentioned by Wijnhoven et al. (2015), there are several motivating factors for citizens to participate in their city, including the playfulness of the participation experience or the learning opportunities it provides.

Therefore, as these two factors were explicitly mentioned by the children when discussing the positive points of the workshop, we are confident that adults would engage in it as well after necessary adaptations, some of which were hinted through practitioners' feedback. In the theoretical introduction step, more realistic and complex examples could be presented. The citizen participation concept could also be discussed more in depth by detailing the different levels of participation that can be implemented (Arnstein, 1969; International Association for Public Participation, 2018; Cardullo and Kitchin, 2019). In the construction of the model step, more realistic budget constraints could be imposed. Through a collaboration with public servants, scenarios based on real-life cases (e.g. the opening of a mall in the center of a city) could be used to structure the discussions and output a more concrete result. Additionally, more advanced roles could be assigned in the group discussion to reflect the roles and structure of a municipal council. In the solution step, more advanced techniques could be used to design smart city solutions with the adults. We intend to source these techniques from the end-user programming field (Lieberman et al., 2006) and to prototype them with participants.

10.2 Inject OGD into the Workshop

The evaluation of the workshop showed that data is needed for children to debate. This was the main rationale behind the development of the tangible interaction table proposing visual aids displaying data associated with each building. However, the current implementation of the tangible interaction table uses fabricated data, generated arbitrarily by comparing each building (e.g. the mall should have a higher impact on congestion than a small grocery store). Although this is an improvement from the paper-based workshop that uses no data at all, this remains quite limiting.

Governments are publishing more and more OGD datasets on a wide set of concerns. This data represents a promising opportunity to improve the realism of the data displayed on the table. When appropriate, OGD datasets could be projected directly onto the table, or OGD could be used to generate more realistic data to display. We expect that it would have a positive impact on the workshop. The interest of children may increase since the workshop would become an opportunity for them to learn more on the domains they explore on the table with true data. Furthermore, it would also allow introducing children to OGD and to its usefulness. Indeed, we concluded from the elicitation of requirements that providing visual representations and demonstrating the range of questions OGD can answer is needed to make lay citizens aware of its relevance and to engage them in OGD use. Of course, we do not expect such young citizens to access OGD portals. That being said, other access modes tailored to children could be envisioned, and we believe that an early sensitization is beneficial to attract them more easily on OGD portals in the future.

However, the currently published OGD might not be sufficient in terms of data granularity at this time. Nonetheless, the state of OGD is moving fast, and this claim should definitely be reevaluated in the future.

10.3 Gamification of OGD Portals

In order to implement lay citizens' requirements, different approaches can be followed. Some authors suggest to better integrate social media and open data (Alexopoulos et al., 2014). Other focus on custom visualizations to make sense of the data and foster transparency (Barcellos et al., 2017). In this paper, we suggest to investigate the gamification literature as a promising way forward, suitable with lay citizens' requirements. Gamification refers to "a design approach of enhancing services and systems with affordances for experiences similar to those created by games" (Koivisto and Hamari, 2019). Numerous mechanisms such as rewards, achievements, defining clear goals and progress paths, have been successful in engaging users in many domains such co-creation and innovation (Leclercq et al., 2018), healthcare (Johnson et al., 2016a; Hammedi et al., 2017), tourism (Moro et al., 2019) or education (Majuri et al., 2018). In a recent systematic literature review, Koivisto and Hamari (2019) summarized the main gamification mechanisms reported in the literature, focusing on results from experimental quantitative studies where clear indications about the results are provided. The most reported mechanisms are: points, badges, leaderboards, quests, levels, timers, rewards, storytelling, dialogues, process, competition, quizzes and virtual helpers.

Since a core issue with OGD is its low use and engagement by lay citizens, gamification constitutes a promising lead to address it. Games and OGD already have connection in the literature through the development of data games, which are "games where gameplay and/or game content is based on real-world data external to the game, and where gameplay supports the exploration of and learning from this data" (Friberger et al., 2013). An example is a Monopoly-like game where the in-game values are computed from indicators about neighborhoods published by the UK government (Friberger and Togelius, 2012). Using OGD from the US Department of Agriculture, Dunwell et al. (2016) have developed minigames designed to promote healthier eating habits. While these games focus on educating to the content of the used datasets, Wolff et al. (2017) developed a board game to educate to the benefits of open data more generally, making players aware of the questions open data can be useful to answer.

However, the goal of these games is to educate the public either on the content of specific datasets or on the relevance of OGD in general. To the best of our knowledge and according to a recent literature review published by Hassan and Hamari (2019), only one study actually examines the use of gamification to improve the design of OGD portals. Indeed, Blazhko et al. (2017) use quizzes and quest-like interface to foster communication between citizens and government by enabling citizens to give feedback on OGD datasets. However, the proposed solution only focuses on feedback features and did not undergo any user evaluation. Thus, although promising, the use of gamification mechanisms to improve the design of OGD portals remains largely underexplored. As a first step to engage in this direction, it would be interesting to build a detailed mapping to determine which gamification mechanisms could answer the requirements of lay citizens, and to implement the features thus identified in an OGD portal prototype to evaluate them with users.

10.4 Public Displays as Conveyors of Open Government Data

While this thesis primarily focuses on the requirements related to the usability of OGD portals (e.g. the need to be able to visualize data, the need to be able to filter data, the need for data to be categorized, or the need to have data quality indicators). However, there are other requirements that should be investigated as well, relating to information needs and socio-collaborative needs (Ojo et al., 2016b; Hogan et al., 2017; Ruijer et al., 2017). Information needs refer to the content of the OGD portal, in terms of datasets that are important for OGD users. Socio-collaborative needs are related to interaction with others when using OGD. For example, the need for a discussion area on the portal, the need for contact information, the need for technical support, or the need to be able to share data with others.

Regarding information needs, the information seeking process involves a search for information (Bar-Ilan et al., 2011) that can be performed in four different ways (McKenzie, 2003). In order to maximize the number of instances where OGD is useful to fulfill an information needs, it is important to accommodate the different information search strategies. The first is active seeking, which refers to asking a specific question to an information source (i.e. in this case, an OGD portal). OGD portals support this strategy by proposing a search engine. The second is active scanning and consists in browsing an information source without specific goal. Again, it is supported by the navigation and browsing features of OGD portals. The third strategy is the proxy, which is another information source that redirects toward the OGD portal. Communication around OGD and redirection from municipal information services support this way of searching information. Finally, the fourth strategy is nondirected scanning and refers to serendipitous encounters with information. This strategy could be supported by social media, for example by encountering a post presenting information based on OGD while browsing one's activity feed. However, while serendipitous, such an encounter with information is subjected to an entry barrier, namely being registered on the social media. Public displays, being exempt from this limitation, could be leveraged to present OGD to citizens in the urban environment, and, what is more, to contextualize the displayed information.

10.5 Integration of Public Displays with Other Participation Methods

In the research agenda on public displays and citizen participation, we explained that while comparing the advantages of participation methods is interesting, the reality is that citizen participation is implemented by several methods that need to be articulated together thoughtfully. Indeed, while too many concurrent methods might overburden citizens and discourage them from participating altogether, combining methods can prove valuable (Blondiaux, 2017). Such complementarity could consist in using the results of one method to fuel another (e.g. a civic hackathon fueled by citizens' input from an online platform and social media (Simonofski et al., 2020a)), or in alleviating the limitations of one method with another (e.g. complete a consultation on social media with a mail consultation to reach citizens who are not on social media). Therefore, when proposing public displays as a new participation method, it is essential to study how they can integrate efficiently with the others.

The first step to achieve this would be to study the literature to identify potential complementarities with public displays. For example, a study found that public displays can attract much more citizens than online platforms but are less suited to collect rich data (Goncalves et al., 2014), thus suggesting interesting complementarities with online platforms. This first step would lead to the identification of candidate methods to be combined with public displays. Then, for each method, a public display prototype would be developed to have a testable implementation of the pair. To be complementary to an online platform, a public display, performing well at conveying information to a large audience and collecting simple data, could show a visual overview of the ideas on a public display and allow voting. The display would also serve as advertisement for the participation platform and redirect citizens interested to contribute a richer feedback, since public displays are not well-suited to collect detailed data. Finally, following the practices of research on public displays, the prototype would be evaluated through a field study. This process can be repeated for each candidate method identified from the literature analysis.

Chapter 11

Conclusion

This thesis addresses three barriers to citizen participation, namely the lack of education to the participatory smart city, the difficult access to usable data, and the entry barrier of current participation methods. These three barriers were selected from a literature review and an analysis of the smart city context of Wallonia. Thus, each barrier is linked to a research gap and a challenge for practice. They were addressed in such a way that the research outputs contribute to both research and practice.

Due to an upcoming education reform, secondary school teachers will be required to discuss technology and democracy in their classes in the near future. The smart city and its participatory orientation are at the intersection of these two themes and thus answer this requirement. By taking into account the timing constraints of in-class activities, we developed a workshop to introduce the participatory smart city to children aged 12 to 14. The workshop was validated extensively and showed success in introducing the concept. Furthermore, the workshop was found enjoyable by children who showed a great enthusiasm during the discussions. The material provided in this thesis and the external resources it refers to give the necessary guideline for teachers to reproduce the workshop in their classes autonomously. Furthermore, another version of the workshop, supported by a tangible interaction table, was developed. It aims at providing visual aids to children to fuel their discussions and at strengthening its playful aspect.

OGD is an extremely diverse and increasingly abundant source of data. It therefore constitutes a promising opportunity to equip citizens with the data they need to participate. However, its use by citizens remains low in practice. Therefore, we analyzed the requirements of expert and lay citizens toward the online portals through which OGD is currently provided and we analyzed the impediments faced by expert users when using OGD for a development project. The output is a detailed list of

26 requirements and 7 impediments. Since we observed that visualizations are demanded by both lay and expert citizens, we conducted a systematic literature review of intra-city traffic data (which is a popular theme for participation and therefore one for which there is demand for data). It allowed elaborating a guide helping OGD portal developers to choose the most appropriate visualization approaches to present mobility to citizens on portals. Finally, from the literature review and the analysis of requirements and impediments, we formulated 4 interface design recommendations to help portal developers and OGD publishers to provide OGD in a way that is more tailored to lay citizens.

Public displays have specificities that make them a promising participation method, and several empirical studies have confirmed their potential. However, the adoption of public displays in citizen participation strategies remains low. Therefore, in order to encourage their adoption, we have conducted a systematic literature review to describe the successful usages of public displays in this regard, from which public servants can draw inspiration for their own participation strategy. From this literature review, we identified four research direction to further encourage the adoption of public displays, two of which we explored further. First, we identified 26 influence relationships between citizens' characteristics and expectations toward electronic services. According to the characteristics of their population, public servants can use these relationships to involve citizens in the development of public electronic services in the most adapted way. Second, we built a process model that helps developers to model adaptation features in public displays.

This thesis contributes to research by addressing its three research gaps. Every research output is a novel contribution and was published or is under submission in a peer-reviewed conference or journal. Furthermore, all the data collection instruments used in this thesis are provided in full and are directly reusable by other researchers. Regarding practice, this thesis provides tools and recommendations destined to help public servants (including OGD publishers), developers, and secondary school teachers to alleviate the three barriers and facilitate citizen participation.

The research presented in this document paves the way for numerous future works. Indeed, it has limitations concerning both its general approach and specific points of individual contributions. We discussed how they were alleviated, and the further research leads they open. Furthermore, we identified four additional future work directions that were not derived from the limitations.

Altogether, this thesis both answers questions and asks new ones. This is the beauty of research, and an elegant way to ensure the funding of the next generation of researchers.

Part V

Appendices

APPENDIX A

INDIVIDUAL ROLE IN PUBLICATIONS

The publication strategy followed in this thesis was to write and submit an article for each contribution that is significant and mature enough. In doing so, the goal was twofold: obtain a feedback from expert peers on the proposed contributions to (1) make the necessary adjustments to improve them, and (2) select the most relevant specific leads to address. The content is thesis is based on and extends the following publications. All the publications and the research they present are the result of collaborations between this thesis' author and his supervisor and/or other researchers. The individual role of this thesis' author is detailed for each publication in Table A.1. The roles are described following the CRediT contributor role taxonomy (Brand et al., 2015), which is presented in Table A.2, reproduced from (Brand et al., 2015).

Table A.1: List of peer-reviewed publications this thesis is based on and individual contribution of the thesis' author.

Publication	Individual contribution
(Simonofski et al., 2018b)	Conceptualization, Methodology, Writing - Review & Editing
(Simonofski et al., 2019a)	Conceptualization, Methodology, Software, Validation, Formal Analysis, Investigation, Resources, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization
(Clarinval et al., 2021b)	Conceptualization, Methodology, Software, Validation, Formal Analysis, Investigation, Resources, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization
(Clarinval et al., 2021a)	Conceptualization, Resources, Writing - Review & Editing, Supervision
(Simonofski et al., 2021a)	Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Resources, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization
(Crusoe et al., 2019)	Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Resources, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization
(Clarinval and Dumas, 2021)	Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Resources, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization
(Clarinval et al., 2021c)	Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Resources, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization
(Clarinval et al., 2019)	Conceptualization, Methodology, Formal Analysis, Investigation, Resources, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization
(Simonofski et al., 2021b)	Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Resources, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization
(Clarinval, 2021)	Conceptualization, Resources, Writing - Original Draft, Writing - Review & Editing

Table A.2: CRediT contributor role taxonomy, reproduced from (Brand et al., 2015).

Role	Definition
Conceptualization	Ideas; formulation or evolution of overarching research goals and aims
Methodology	Development or design of methodology; creation of models
Software	Programming, software development; designing computer programs; implementation of the computer code and supporting algorithms; testing of existing code components
Validation	Verification, whether as a part of the activity or separate, of the overall replication/ reproducibility of results/experiments and other research outputs
Formal analysis	Application of statistical, mathematical, computational, or other formal techniques to analyze or synthesize study data
Investigation	Conducting a research and investigation process, specifically performing the experiments, or data/evidence collection
Resources	Provision of study materials, reagents, materials, patients, laboratory samples, animals, instrumentation, computing resources, or other analysis tools
Data Curation	Management activities to annotate (produce metadata), scrub data and maintain research data (including software code, where it is necessary for interpreting the data itself) for initial use and later reuse
Writing - Original Draft	Preparation, creation and/or presentation of the published work, specifically writing the initial draft (including substantive translation)
Writing - Review & Editing	Preparation, creation and/or presentation of the published work by those from the original research group, specifically critical review, commentary or revision – including pre-or postpublication stages
Visualization	Preparation, creation and/or presentation of the published work, specifically visualization/ data presentation
Supervision	Oversight and leadership responsibility for the research activity planning and execution, including mentorship external to the core team
Project administration	Management and coordination responsibility for the research activity planning and execution
Funding acquisition	Acquisition of the financial support for the project leading to this publication

APPENDIX B

Questionnaire for Workshop Evaluation

B.1 Pre-test Questionnaire

If you have difficulties answering the questions, you can simply write the first words that come to your mind, give examples, draw a picture, etc. There are no wrong answers. It is your opinion that counts.
For you, a city is ...
For you, a smart city is ...
List the positive and negative points of group discussions.

B.2 Post-test Questionnaire

If you have difficulties answering the questions, you can simply write the first words that come to your mind, give examples, draw a picture, etc. There are no wrong answers. It is your opinion that counts.
For you, a city is ...
For you, a smart city is ...
List the positive and negative points of the smart city activity.
What is the smart city project you would like to see in your city?
How would you ask the population's opinion on a smart city project?

APPENDIX C

QUESTIONNAIRE AND INTERVIEW GUIDE FOR EXPERT CITIZENS' BARRIERS TO OGD USE

C.1 Questionnaire

Introduction							
Q1. Can you provide your name or a brief description of the project you worked on? (this will be used to aggregate the answers by project)							
Q2. What is your background? O Management O Computer science O Mathematics O Science O Other							
Q3. How confident are you with							
Programming	Not confident at all	☐	☐	☐	☐	☐	Very confident
Data analysis	Not confident at all	☐	☐	☐	☐	☐	Very confident
Open data portals	Not confident at all	☐	☐	☐	☐	☐	Very confident
Start and motivation							
Q4. For each of the tasks below, please indicate how difficult it was with the following scale.							
Finding the idea	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier
Finding an idea applicable to Namur	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier
Finding "use case" examples of open data	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier
Understanding the requirements of potential users of the project	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier
Conducting a feasibility study of the idea	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier

Search and evaluate							
Q5. For each of the tasks below, please indicate how difficult it was with the following scale.							
Search functionality	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier
Search results presentation	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier
Quality of metadata	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier
Had to download the data to evaluate it	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier
The tools for exploring of, analyzing of, or experimenting with data	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier
Open data portal language	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier
License impedes the use	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier
Must log in to evaluate and access the data	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier
Access and prepare							
Q6. For each of the tasks below, please indicate how difficult it was with the following scale.							
Wrong type of access (manual vs automated)	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier
Complex access with documentation	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier
Filtering useful data	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier
Relevancy of data formats	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier
Data quality (e.g. missing essential information)	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier
Lack of documentation to prepare data (e.g. conversion tables)	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier
Data is inaccessible because of paywalls, limitations of infrastructure, or demands of registrations	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier
No support (e.g. lack of documentation or forums)	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier
Aggregate and transform							
Q7. For each of the tasks below, please indicate how difficult it was with the following scale.							
Data cannot be combined	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier
Data quality varies	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier
Data availability varies	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier
Tools cannot combine the data sources	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier
No longitudinal data	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier
Data infrastructure cannot be integrated	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier
Data needs special knowledge to understand	Not a barrier	☐	☐	☐	☐	☐	Extreme barrier

Resource allocation							
Q8. Please rank the four phases from most-time consuming (1) to least time-consuming (4)							
☐ Start and motivation							
☐ Search and evaluate							
☐ Access and prepare							
☐ Aggregate and transform							
Resource allocation							
Q9. Do you think the time invested in the following phases was useful to the final output of your project?							
Start and motivation	Very useful	☐	☐	☐	☐	☐	Not useful at all
Search and evaluate	Very useful	☐	☐	☐	☐	☐	Not useful at all
Access and prepare	Very useful	☐	☐	☐	☐	☐	Not useful at all
Aggregate and transform	Very useful	☐	☐	☐	☐	☐	Not useful at all
Final questions							
Q10. Have you applied the 4 phases above sequentially or iteratively?							
O Sequentially							
O Iteratively							
Q11. Did you have to learn new technologies, techniques, concepts to carry out the project?							
Q12. Which open data portals did you use?							
☐ Namur							
☐ London							
☐ New-York							
☐ Paris							
Q13. Are there any reasons why you did not use specific portals?							
Q14. Do you have additional comments on open data portals?							

C.2 Interview Guide

The interview starts with a brief reminder of the phases. The interview is structured into six parts: introductory questions, phase-specific questions (for each of the four phases), and concluding questions.

C.2.1 Introduction

(i) To warm up, give us a brief presentation of your project and how you worked with it.
(ii) In the survey we had the phases start of the project, search and evaluate, access and prepare, and aggregate and transform. How do you think this fitted with how you worked? Is any activity missing? If so, which?
(iii) Rank the four phases by difficulty.

C.2.2 Start and Motivation

Main barriers: finding the idea, finding an idea applicable to Namur, and finding “Use-case” examples of Open Data.

(i) Was it difficult to find an idea of application for open data? Why? What was particularly tough?
(ii) If not, did you experience any barriers at the start of the project? If so, what barriers and how did they impact your work?

C.2.3 Search and Evaluate

Main barriers: quality of metadata.

(i) What was your overall barriers when using the Open Data Portal? Give an example.
(ii) Did you experience any barriers with the quality of the metadata? If so, how did they impact your work? Give examples.
(iii) If not, did you encounter any barriers when searching for the right data? If so, what barriers did you encounter? How did they impact your work? Give examples.

C.2.4 Access and Prepare

Main barriers: relevance of data formats and data quality.

(i) Did you experience any barriers from the data formats or data quality. If so, how did they impact you work? Give examples.
(ii) If not, did you encounter any barriers when accessing and preparing data? If so, what barriers and how did they impact your work? Give examples.

C.2.5 Aggregate and Transform

Main barriers: data cannot be combined, data availability varies, tools cannot combine the data sources, and no longitudinal data.

(i) Did you experience any barriers when trying to combine and use the data in the product? If so, tell us about it. How did they impact your work? Give examples.
(ii) If not and if you did experience any other barriers, what barriers did you encounter and how did they impact your work? Give examples.

C.2.6 Conclusion

(i) If the barriers persisted, would you be motivated to continue developing a product or service on open data? Why?
(ii) What is your dream scenario for working with open data?
(iii) What do you need to get there? How can publishers and open data portals support you?
(iv) Is there anything you think we have forgotten to ask about? Or something relating to the project you want to tell us about?
(v) Did you experience any barriers not captured by the survey or mentioned in the interview? If so, give some examples.

APPENDIX D

Analysis of Lay citizens' Requirements On OGD Portals

D.1 Recruitment Questionnaire

The goal of the following questions is to identify participants interested to know more about OGD and be part of our research. Furthermore, it helps us to distinguish the lay citizens (with low ICT and development skills) from the experts.

Q1. The city of Namur has a website with data for citizens. For example, data about their budget, the schools in the city and the recreational areas are available. Are you aware of the website where the city publishes this type of data for its citizens? *[Show a screenshot of the OGD portal of Namur]* O Yes O No							
Q2. How would you qualify your ICT skills (e.g. using tables, exploring datasets)?							
ICT skills	Very low	☐	☐	☐	☐	☐	Very high
Q3. How would you qualify your development skills (e.g. using tables, exploring datasets)?							
Development skills	Very low	☐	☐	☐	☐	☐	Very high
Q4. Are you interested to learn more about the websites that the city of Namur uses to publish data that can be accessed by citizens? O Yes O No							
If answer to Q4 is [Yes] Q5. Are you interested to participate in our research? O Yes O No							
If answer to Q5 is [Yes] Please leave your contact information. Your participation will consist in a 1-hour interview. No specific expertise is needed and the data extracted from the interview will be processed anonymously.							

D.2 Interview Guide

The goal of the following questions is to identify the requirements of experts and lay citizens toward OGD portals. The objectives are more extensively described in the following consent form. [The researcher presents the consent form and proceeds if the interviewee agrees to sign it]. The questions are structured around the four main phases of OGD use, as described in Section 2 of this paper.

D.2.1 Start and motivation

- What comes to mind when I mention the term "open data"? You can mention anything you think of.

[The researcher then presents a simplified definition of OGD: Open data refers to data (e.g. about budget, schools or recreational areas) put on a website by public organizations available for re-use. This data can be useful for businesses, other organizations or citizens directly.]

- Have you ever used open data? *[Yes / No]*
  - If so, what was the topic of the data you used? And what did you do with them?
  - If so, what motivated you to use open data?
  - If not, why not?
- Do you plan to use open data in the future? *[Yes / No]*
  - If so, why, and what types of data would you like to access on municipal websites? *[The question is first open. Then, provide a list of high-value datasets*[1] *and ask the three datasets that are most interesting for the respondent]*
  - If not, why not?
- How would you envision the website should look like? What should be the main tasks it should allow you to do?
- Would you like this website to be publicized to you? If yes, through which channels (social media, newspaper, mails, website, etc.) would you like it to be publicized to you?

[The researcher then shows the OGD portal of Namur without additional explanation]

- To what extent does this website meet your expectations of open data?
  - *[If the interviewee had experience with portals before]* How does this open data website differ from the one(s) you used before?

[The interviewee then performs a use scenario on the portal, trying to access and exploit data, selected among the cited datasets of the previous questions. The researcher invites the interviewees to mention his/her thoughts and feelings over the portal orally. After, specific questions are asked.]

[1] https://data.overheid.nl/community/maatschappij/high-value/gemeenten

D.2.2 Search and evaluate

- How would you assess the ability to explore the data on the website? What is your opinion about the categorization of the data?
- Are there any other categories that would be useful when using data from the municipality of Namur?
- What do you think of the index cards presenting the datasets? *[The researcher points at the cards if necessary]*
- To what extent do the index cards provide the information that you need to use data on the website of the municipality of Namur? Is this how you would like the categorization to be presented to you?
- To what extent are the information tabs from the index cards of the dataset understandable? Do you need any additional information about the data to get a basic understanding of them? If yes, what additional information would you need?
- Would any extra information help you in the search of the relevant data? If yes, what additional information would support your use of the data?

D.2.3 Access and prepare

- On a scale from 1 to 10, where 1 stands for very difficult and 10 stands for very easy, how difficult or easy was it to you to get access to a dataset on the website of the municipality of Namur? Could you please explain your answer?
- Which format do you think the data should have after download ? *[The researcher lists examples such as PDF, Word, Excel or JSON if the interviewee does not know what a data format is]*
- How do you evaluate the overall data quality of the accessed dataset? What do you think are the most important quality indicators?

D.2.4 Aggregate and transform

- How would you prefer municipality data to be presented to you?
- Would a visualization be useful to present the data? *[Yes / No]*
  - If so, which type of visualization?
- How do you evaluate the overall data quality of the accessed dataset? What do you think are the most important quality indicators?
- To what extent do you need extra information for facilitating your use of the data?
- Would you like to give feedback about the OGD portal to the publishing organization? *[Yes / No]*
  - If so, how?
  - If not, what would encourage you to give feedback?

D.2.5 Closing questions

- After this session, would you be inclined to use an OGD portal in the future? *[Yes / No]*
  - If so, why?
  - If not, why not?
- Are there conditions under which you would use open data more often? *[Yes / No]*
  - If so, which conditions?
- ADo you have other expectations, wishes or requirements related to the municipality website that we did not discuss during this interview? *[Yes / No]*
  - If so, please give some examples.

[The researcher reminds the interviewee that the data will be analyzed anonymously to only extract relevant requirements. Furthermore, all personal data will be deleted.]

APPENDIX E

SUPPLEMENTARY MATERIAL TO THE SYSTEMATIC LITERATURE REVIEW ON INTRA-CITY TRAFFIC DATA VISUALIZATION

This appendix provides the full counts related to the Section 7.4.2 (Tables E.1 to E.10) as well as the categorization information for each of the surveyed works (Tables E.11 to E.20).

Table E.1: Frequency of the data sources per domain.

Domain	Citizens	Auth.	Transp.	Phone	Other PC	Research	API	IoT	Simul.
Mobility patterns	**17**	14	**16**	15	8	2	3	4	4
Congestion	3	**11**	7	0	3	4	1	8	7
Microscopic movements	0	2	2	0	2	2	0	**3**	2
Public transportation use	1	2	**10**	0	0	0	0	0	0
Accessibility/travel time	2	2	**4**	0	**3**	0	2	0	2
Accidents	1	**7**	0	0	0	1	0	2	1
Pollution	0	0	0	0	0	0	0	2	**4**
Anomaly detection	0	1	0	0	0	1	0	1	0
Route recommendation	0	0	1	0	0	0	0	0	0
Parking availability	1	0	0	0	0	0	0	1	0

Table E.2: Frequency of the visualization architectures per domain.

Domain	1T	nT	2D	2D+1T	2D+nT	3D	3D+1T	3D+nT	2D+3D	2D+3D+1T	2D+3D+nT
Mobility patterns	3	2	12	11	**37**	0	1	1	1	2	3
Congestion	1	1	**16**	3	12	2	0	0	1	3	1
Microscopic movements	0	0	**5**	2	**5**	1	0	0	0	0	0
Public transportation use	2	0	2	0	**5**	0	1	1	0	0	1
Accessibility/travel time	0	0	**4**	1	**5**	1	0	0	1	0	0
Accidents	0	0	1	**4**	**4**	1	0	0	0	0	0
Pollution	0	0	**2**	1	1	**2**	0	0	0	0	0
Anomaly detection	0	1	0	1	1	0	0	0	0	0	1
Route recommendation	0	0	0	0	**2**	0	0	0	0	0	0
Parking availability	0	0	0	1	1	0	0	0	0	0	0

Table E.3: Frequency of the geospatial visualization techniques per domain.

Domain	Point-based map			Line-based map			Area-based map		
	DM	SM	GSM	NM	ONM	FM	CAM	OCM	CM
Mobility patterns		**56**			46			14	
	17	1	47	15	1	40	0	3	12
Congestion		27			**31**			1	
	10	0	20	8	7	21	0	1	0
Microscopic movements		**9**			**8**			0	
	4	0	6	3	0	6	0	0	0
Public transportation use		**7**			**8**			2	
	4	0	6	4	1	5	0	1	2
Accessibility/travel time		3			**7**			4	
	0	0	3	2	0	5	0	1	3
Accidents		**8**			6			0	
	4	0	5	1	3	3	0	0	0
Pollution		**4**			**3**			1	
	0	0	4	1	1	2	0	0	1
Anomaly detection		**2**			**3**			0	
	2	0	1	2	0	3	0	0	0
Route recommendation		**2**			1			0	
	0	0	2	0	0	1	0	0	0
Parking availability		**2**			0			0	
	0	0	2	0	0	0	0	0	0

Note: The totals of the three map subtypes might add to more than the frequency of the upper map type. For example, if an article uses a dot map and a graduated symbol map, each subtype would be incremented, whereas the count related to point-based maps would increment by only 1.

Table E.4: Frequency of the non-geospatial visualization techniques per domain.

Domain	Heatmap	Line chart	Histogram	Scatterplot	Bar chart	PCP	Stacked hist.	N-L diagram
Mobility patterns	**28**	23	18	9	8	11	8	7
Congestion	**13**	9	6	7	3	4	6	1
Microscopic movements	**5**	**4**	2	**4**	1	1	2	0
Public transportation use	**4**	2	2	1	2	1	0	0
Accessibility/travel time	1	1	0	1	1	0	**2**	0
Accidents	**5**	**4**	3	**4**	1	1	0	0
Pollution	1	1	0	0	1	0	0	0
Anomaly detection	**5**	1	2	1	0	2	0	1
Route recommendation	0	0	0	0	0	1	2	0
Parking availability	0	1	1	0	1	0	0	0

Table E.5: Frequency of the visualization architectures per data source.

Data source	1T	nT	2D	2D+1T	2D+nT	3D	3D+1T	3D+nT	2D+3D	2D+3D+1T	2D+3D+nT
Citizens	1	1	**8**	4	**7**	0	1	1	1	0	1
Authorities	1	0	8	2	**16**	2	0	0	1	3	1
Transport service	3	0	5	1	**10**	1	1	2	0	0	1
Phone operator	1	0	1	3	**8**	0	0	0	0	1	1
Other private company	0	0	2	3	**8**	0	0	0	0	1	0
Research project	0	1	1	1	**3**	0	0	0	0	0	1
Internet of Things	0	2	4	3	**7**	0	0	0	0	0	0
Simulated	0	0	**8**	1	3	3	0	0	0	1	0

Table E.6: Frequency of the geospatial visualization techniques per data source.

Data source	Point-based map			Line-based map			Area-based map		
	DM	SM	GSM	NM	ONM	FM	CAM	OCM	CM
Citizens		**17**			15			6	
	7	1	12	3	3	10	0	1	6
Authorities		**25**			21			5	
	8	0	21	5	3	17	0	1	4
Transport service		**15**			12			4	
	5	0	14	6	1	9	0	1	4
Phone operator		**13**			10			3	
	4	0	12	5	0	9	0	2	1
Other private company		9			**12**			1	
	3	0	7	1	1	11	0	0	1
Research project		**5**			**4**			1	
	1	0	5	0	0	4	0	1	0
Internet of Things		**9**			**9**			1	
	4	0	7	3	3	4	0	0	1
Simulated		**10**			**10**			2	
	4	0	7	4	0	7	0	0	2

Note: The totals of the three map subtypes might add to more than the frequency of the upper map type. For example, if an article uses a dot map and a graduated symbol map, each subtype would be incremented, whereas the count related to point-based maps would increment by only 1.

Table E.7: Frequency of the non-geospatial visualization techniques per data source.

Data source	Heatmap	Line chart	Histogram	Scatterplot	Bar chart	PCP	Stacked hist.	N-L diagram
Citizens	**8**	**7**	3	3	2	0	0	0
Authorities	**13**	10	6	9	3	4	4	2
Transport service	6	**8**	3	1	4	0	2	0
Phone operator	**5**	**5**	3	3	1	3	2	1
Other private company	**5**	3	**4**	3	3	1	2	2
Research project	**5**	**4**	1	1	2	1	1	1
Internet of Things	**5**	**5**	**6**	2	3	1	1	0
Simulated	2	**4**	1	1	0	0	0	0

Table E.8: Frequency of the visualization architectures per target end-user.

Target end-user	1T	nT	2D	2D+1T	2D+nT	3D	3D+1T	3D+nT	2D+3D	2D+3D+1T	2D+3D+nT
Citizens only	0	1	**3**	2	**3**	1	0	0	0	0	0
Experts only	5	4	24	13	**51**	4	2	1	1	5	5
Both citizens and experts	0	0	**6**	3	4	1	0	1	0	0	0
Unspecified	0	0	**4**	0	1	0	0	0	1	0	0

Table E.9: Frequency of the geospatial visualization techniques per target end-user.

Target end-user	Point-based map			Line-based map			Area-based map		
	DM	SM	GSM	NM	ONM	FM	CAM	OCM	CM
Citizens only		**6**			**7**			0	
	4	0	3	4	1	3	0	0	0
Experts only		**78**			70			19	
	23	1	65	19	10	53	0	5	16
Both citizens and experts		**11**			**10**			1	
	5	0	8	2	0	9	0	1	0
Unspecified		**4**			**3**			2	
	1	0	4	1	0	2	0	0	2

Note: The totals of the three map subtypes might add to more than the frequency of the upper map type. For example, if an article uses a dot map and a graduated symbol map, each subtype would be incremented, whereas the count related to point-based maps would increment by only 1.

Table E.10: Frequency of the non-geospatial visualization techniques per target end-user.

Target end-user	Heatmap	Line chart	Histogram	Scatterplot	Bar chart	PCP	Stacked hist.	N-L diagram
Citizens only	**2**	1	0	1	**2**	0	**2**	0
Experts only	**43**	35	25	17	13	11	12	7
Both citizens and experts	**3**	**2**	1	1	1	**2**	0	0
Unspecified	0	1	1	1	0	1	0	0

Table E.11: Primary studies reviewed with the information extracted for the six SRQ (1/10).

Ref.	**Year**	**Publish.**	**Target users**	**Data realness**	**Data source**	**Data availability**	**Visualization techniques**	**Architecture**	**Time representation**	**Compliance to mantra**	**Domain**	**User study (# partic.)**
(Guillén et al., 2011)	2011	ACM	citizens	true, simulated	citizens (volunteered tracking), simulated	static, real-time	2D dot map, 2D flow map, 2D graduated symbol map	2D	none	compliant	congestion	no
(Pu et al., 2011)	2011	ACM	unspecified	true	phone operator	static	2D choropleth map, 2D flow map, 2D graduated symbol map, histogram, line chart, mosaic plot, parallel coordinates plot, scatterplot	2D+nT	non-geospatial technique, flatten (length)	compliant	mobility patterns	no
(Bak et al., 2012)	2012	ACM	experts	true	transport service	static	2D graduated symbol map	2D	symbol on GSM	not compliant	congestion	no
(Debiasi et al., 2013)	2013	ACM	experts	simulated	simulated	real-time	3D flow map, 3D graduated symbol map	3D	none	not compliant	congestion, pollution	no
(Bast et al., 2014)	2014	ACM	unspecified	true	transport service	static, real-time	2D dot map, 2D graduated symbol map, 2D network map	2D	animation	compliant	public transportation use	no
(Nagel et al., 2014)	2014	ACM	experts, citizens	true	authorities (public transport)	static	2D graduated symbol map, arc diagram, bubble chart	2D+nT	non-geospatial technique, animation	compliant	public transportation use	yes (27)
(Somdulyawat et al., 2015)	2015	ACM	experts	true	transport service	static	3D choropleth map, 3D graduated symbol map, histogram	3D+1T	non-geospatial technique, animation	compliant	public transportation use	yes (50)
(Cristie et al., 2015)	2015	ACM	experts, citizens	simulated	simulated	static	2D graduated symbol map	2D	animation	compliant	pollution	no
(Zhang et al., 2015)	2015	ACM	unspecified	true	unspecified (taxi)	static	2D choropleth map	2D	none	compliant	mobility patterns	no
(Yin et al., 2015)	2015	ACM	experts	true	authorities, transport service	static	2D choropleth map	2D	none	compliant	accessibility/travel time	yes (6)
(Splechtna et al., 2016)	2016	ACM	experts	true	authorities (public transport)	static	2D dot map, 2D network map, histogram, parallel coordinates plot, scatterplot	2D+nT	non-geospatial technique	compliant	public transportation use	no
(Singhal et al., 2016)	2016	ACM	experts, citizens	simulated	simulated	static, real-time	2D dot map, 2D network map	2D	none	not compliant	congestion, microsc. mov.	no
(Skelton et al., 2017)	2017	ACM	experts	true	citizens (questionnaire)	static	3D graduated symbol map, bar chart	3D+1T	non-geospatial technique	not compliant	mobility patterns	no
(Romano and Jiang, 2017)	2017	ACM	experts	true	authorities	static	3D ordered network map	3D	3D	not compliant	accidents	no
(Xu et al., 2018)	2018	ACM	experts, citizens	simulated	simulated	static	3D dot map	3D	animation	compliant	microsc. mov.	yes (20)
(Schoedon et al., 2019)	2019	ACM	experts, citizens	true	online api (unspecified)	real-time	2D flow map	2D	none	not compliant	accessibility/travel time	no
(Feng et al., 2020)	2020	ACM	experts	true, simulated	authorities (open data), simulated	static	2D graduated symbol map, heatmap, histogram, line chart, scatterplot, sunburst diagram	2D+nT	non-geospatial technique	not compliant	accidents	no

Table E.12: Primary studies reviewed with the information extracted for the six SRQ (2/10).

Ref.	Year	Publish.	Target users	Data realness	Data source	Data availability	Visualization techniques	Architecture	Time representation	Compliance to mantra	Domain	User study (# partic.)
(Dai et al., 2019)	2020	ACM	experts	true	authorities (taxi), transport service	static	2D graduated symbol map, area chart, line chart, sunburst diagram	2D+nT	non-geospatial technique	compliant	mobility patterns	no
(Andrienko and Andrienko, 2008)	2008	IEEE	experts	true	authorities	static	2D flow map, 2D graduated symbol map, heatmap, stacked histogram	2D+nT	symbol on GSM, non-geospatial technique	compliant	mobility patterns	no
(Pack et al., 2009)	2009	IEEE	experts	true	authorities	static	2D graduated symbol map, bar chart, bubble chart heatmap, parallel coordinates plot, scatterplot	2D+nT	non-geospatial technique	compliant	accidents	yes (unspecified)
(Andrienko et al., 2009)	2009	IEEE	experts	true	authorities	static	2D dot map, 2D flow map, 2D network map	2D	none	compliant	mobility patterns	no
(VanDaniker, 2009)	2009	IEEE	experts	true	authorities	static	2D dot map, heatmap, scatterplot, span chart	2D+nT	non-geospatial technique	compliant	accidents	yes (120)
(Pamanikabud and Tansatcha, 2010)	2010	IEEE	experts	simulated	simulated	static	3D graduated symbol map	3D	none	not compliant	pollution	no
(Chen et al., 2010)	2010	IEEE	unspecified	true	citizens (volunteered tracking)	static	2D graduated symbol map, 3D graduated symbol map	2D+3D	3D	not compliant	accessibility/travel time, mobility patterns	no
(Kang et al., 2010)	2010	IEEE	experts	true	phone operator	static	2D graduated symbol map, 2D network map, 3D flow map, scatterplot	2D+3D+1T	non-geospatial technique, 3D	not compliant	mobility patterns	no
(Endarnoto et al., 2011)	2011	IEEE	citizens	true	citizens (social media)	static	2D dot map, 2D ordered network map	2D	none	not compliant	congestion	no
(Guo et al., 2011)	2011	IEEE	experts	true	sensor network	static	2D flow map, 2D network map, histogram, parallel coordinates plot, scatterplot, stream graph	2D+nT	non-geospatial technique, animation	compliant	microsc. mov., congestion, mobility patterns	yes (unspecified)
(Liu et al., 2011)	2011	IEEE	experts	true	unspecified (taxi)	static	2D flow map, 2D graduated symbol map, parallel coordinates plot, stacked histogram	2D+nT	non-geospatial technique	compliant	mobility patterns, congestion, route recommendation	no
(Wu et al., 2012)	2012	IEEE	citizens	true	citizens (social media)	static	proportional area chart, scatterplot	nT	not applicable	compliant	depends what citizens publish on social media	yes (unspecified)
(Morris et al., 2012)	2012	IEEE	experts	true	cameras	real-time	2D ordered network map, bar chart, line chart	2D+nT	non-geospatial technique	not compliant	pollution	no
(Andrienko et al., 2012a)	2012	IEEE	experts	true	authorities	static	2D flow map, 3D flow map, heatmap	2D+3D+1T	non-geospatial technique, 3D	compliant	congestion	no
(Tominski et al., 2012)	2012	IEEE	experts	true	research project (taxi)	static	2D graduated symbol map, 3D flow map, heatmap, stacked histogram	2D+3D+nT	non-geospatial technique, 3D	compliant	congestion	yes (15)
(Nguyen et al., 2012)	2012	IEEE	citizens	true	transport service	static	3D network map	3D	3D	not compliant	accessibility/travel time	no

Table E.13: Primary studies reviewed with the information extracted for the six SRQ (3/10).

Ref.	Year	Publish.	Target users	Data realness	Data source	Data availability	Visualization techniques	Architecture	Time representation	Compliance to mantra	Domain	User study (# partic.)
(Puertas et al., 2013)	2013	IEEE	experts	true	sensor network	static	2D dot map, 2D graduated symbol map, area chart	2D+1T	non-geospatial technique	compliant	accidents	no
(Di Lorenzo et al., 2013)	2013	IEEE	experts	true	citizens (social media)	static	2D choropleth map, 2D graduated symbol map, 2D network map, chord diagram, line chart, word cloud	2D+nT	non-geospatial technique	compliant	mobility patterns	yes (unspecified)
(Tanahashi and Ma, 2013)	2013	IEEE	citizens	true	online api (Google)	real-time	2D dot map, heatmap, word cloud	2D+nT	non-geospatial technique	compliant	mobility patterns	yes (13)
(Hoang et al., 2013)	2013	IEEE	experts	true	sensor network	static	2D choropleth map	2D	none	not compliant	pollution	no
(Pu et al., 2013)	2013	IEEE	experts	true	unspecified (taxi)	static	2D graduated symbol map	2D	symbol on GSM	compliant	mobility patterns, microsc. mov.	no
(Liu et al., 2013)	2013	IEEE	experts, citizens	true	unspecified (taxi)	static	2D graduated symbol map	2D	symbol on GSM	compliant	mobility patterns	no
(Ferreira et al., 2013)	2013	IEEE	experts	true	authorities (taxi)	static	2D choropleth map, 2D dot map, 2D graduated symbol map, bar chart, line chart, scatterplot	2D+nT	non-geospatial technique	compliant	mobility patterns	no
(Wang et al., 2013)	2013	IEEE	experts	true	private company (not in the transport sector) (taxi)	static	2D flow map, 2D ordered network map, bar chart, heatmap, histogram, scatterplot	2D+nT	non-geospatial technique	compliant	congestion	no
(Wang et al., 2014a)	2014	IEEE	experts	true	transport service	static	2D graduated symbol map, heatmap, line chart, scatterplot, stacked histogram	2D+nT	non-geospatial technique	compliant	microsc. mov., congestion	no
(Wörner and Ertl, 2014)	2014	IEEE	experts	true	transport service	static	line chart	1T	not applicable	not compliant	congestion	yes (unspecified)
(Krüger et al., 2014)	2014	IEEE	experts	true	private company (not in the transport sector), unspecified, citizens (social media)	static	2D flow map, 2D graduated symbol map, heatmap	2D+1T	non-geospatial technique, animation	compliant	mobility patterns	no
(Anwar et al., 2014)	2014	IEEE	experts	true	sensor network, unspecified	static	2D dot map, 2D ordered network map, histogram	2D+1T	non-geospatial technique	not compliant	accidents, congestion	yes (unspecified)
(Wang and Yuan, 2014)	2014	IEEE	experts	true	private company (not in the transport sector) (taxi)	static	2D flow map, 3D area graph, 3D line chart, heatmap, scatterplot, stream graph	2D+nT	non-geospatial technique	not compliant	microsc. mov., accessibility/travel time	no
(Wang et al., 2014b)	2014	IEEE	experts	true	cameras	static	2D graduated symbol map, heatmap, line chart, scatterplot, stacked histogram	2D+nT	non-geospatial technique, animation	compliant	microsc. mov., congestion	no
(Itoh et al., 2014)	2014	IEEE	experts, citizens	true	transport service, citizens (social media)	static	3D flow map, heatmap, proportional area chart	3D+nT	non-geospatial technique, animation	compliant	public transportation use	no

Table E.14: Primary studies reviewed with the information extracted for the six SRQ (4/10).

Ref.	Year	Publish.	Target users	Data realness	Data source	Data availability	Visualization techniques	Architecture	Time representation	Compliance to mantra	Domain	User study (# partic.)
(Quadir et al., 2014)	2014	IEEE	experts	true	cameras	static	2D dot map, 2D network map, bar chart	2D+1T	none	not compliant	congestion, microsc. mov.	no
(Chu et al., 2014)	2014	IEEE	experts, citizens	true	unspecified (taxi)	static	2D flow map, line chart, parallel coordinates plot, timeline, word cloud	2D+nT	non-geospatial technique	compliant	mobility patterns	no
(Zeng et al., 2014)	2014	IEEE	experts	true	transport service	static	2D graduated symbol map, stacked histogram, tree	2D+nT	non-geospatial technique	compliant	accessibility/travel time, route recommendation	yes (2)
(Di Lorenzo et al., 2015)	2015	IEEE	experts	true	phone operator, transport service	static	2D dot map, 2D flow map, 2D network map, line chart, bar chart	2D+nT	non-geospatial technique	compliant	mobility patterns	yes (unspecified)
(Dash et al., 2015)	2015	IEEE	citizens	true	phone operator	static	2D flow map, 2D graduated symbol map, 2D network map, stacked histogram	2D+1T	non-geospatial technique	compliant	mobility patterns	no
(Simmons et al., 2015)	2015	IEEE	experts	true	sensor network	static	2D graduated symbol map	2D	none	not compliant	congestion	no
(Chen et al., 2015a)	2015	IEEE	experts	true	citizens (social media)	static	2D flow map, 2D graduated symbol map, heatmap, histogram, line chart, sankey diagram, word cloud	2D+nT	non-geospatial technique	compliant	mobility patterns	no
(Yu et al., 2015)	2015	IEEE	experts	true	transport service	static	3D choropleth map, 3D flow map, 3D graduated symbol map, histogram, span chart	3D+nT	non-geospatial technique, 3D	compliant	mobility patterns	no
(Von Landes-berger et al., 2015)	2015	IEEE	experts	true	phone operator, citizens (social media)	static	2D flow map, 2D graduated symbol map, heatmap	2D+1T	non-geospatial technique	compliant	mobility patterns	no
(Sinnott et al., 2015)	2015	IEEE	unspecified	true	authorities	static	2D graduated symbol map	2D	none	not compliant	congestion	no
(Wu et al., 2015)	2015	IEEE	experts	true	phone operator	static	2D graduated symbol map, heatmap, parallel coordinates plot, sunburst diagram	2D+nT	non-geospatial technique	compliant	mobility patterns	yes (3)
(Petrovska and Stevanovic, 2015)	2015	IEEE	experts	true	online api (Google)	real-time	2D ordered network map	2D	none	compliant	congestion	no
(ElHakim et al., 2015)	2015	IEEE	experts, citizens	true	cameras	real-time	2D flow map	2D	none	compliant	congestion	no
(Huang et al., 2015)	2015	IEEE	experts	true	research project (taxi)	static	2D flow map, 2D graduated symbol map, line chart, node-link diagram	2D+nT	symbol on GSM, non-geospatial technique	compliant	mobility patterns	yes (15)
(Lu et al., 2015)	2015	IEEE	experts	true	private company (not in the transport sector) (taxi)	static	2D flow map, area chart, box plot, parallel sets, stacked histogram	2D+nT	non-geospatial technique, animation	compliant	accessibility/travel time	yes (7)
(Zheng et al., 2015)	2015	IEEE	experts	true	unspecified (taxi)	static	2D graduated symbol map, histogram, line chart, parallel coordinates plot	2D+nT	non-geospatial technique	compliant	mobility patterns	yes (3)

Table E.15: Primary studies reviewed with the information extracted for the six SRQ (5/10).

Ref.	Year	Publish.	Target users	Data realness	Data source	Data availability	Visualization techniques	Architecture	Time representation	Compliance to mantra	Domain	User study (# partic.)
(Bak et al., 2015)	2015	IEEE	experts	true	authorities (open data)	static	2D flow map, 2D graduated symbol map	2D	symbol on GSM	not compliant	microsc. mov.	no
(Draghici et al., 2015)	2015	IEEE	experts	true	wifi detection	static	2D dot map, 2D graduated symbol map, 2D network map, histogram, line chart	2D+nT	non-geospatial technique	not compliant	mobility patterns	no
(Palomo et al., 2015)	2015	IEEE	experts	true	transport service	static	heatmap	1T	not applicable	compliant	public transportation use	yes (1)
(Anggraini et al., 2016)	2016	IEEE	experts	true	citizens (social media)	real-time	2D ordered network map	2D	none	not compliant	congestion	no
(Cruz and Machado, 2016)	2016	IEEE	experts, citizens	true	private company (not in the transport sector), research project	static	2D dot map, 2D flow map, 2D graduated symbol map	2D	animation	not compliant	congestion, microsc. mov.	no
(Dash et al., 2016)	2016	IEEE	experts	true	phone operator	static	2D dot map, 2D flow map, 2D graduated symbol map	2D	none	compliant	mobility patterns	no
(Krueger et al., 2016)	2016	IEEE	experts	true	citizens (social media), authorities (taxi)	static	2D choropleth map, 2D flow map, area chart, histogram, scatterplot	2D+nT	non-geospatial technique	compliant	mobility patterns	no
(Gupta et al., 2016)	2016	IEEE	experts	true	citizens (volunteered tracking)	static	2D dot map, gantt chart, heatmap	2D+nT	non-geospatial technique	compliant	mobility patterns	no
(Montero et al., 2017)	2017	IEEE	experts	simulated	simulated	static	2D flow map, 2D graduated symbol map, 2D network map, heatmap	2D+1T	none	compliant	congestion, pollution, mobility patterns	no
(Wang et al., 2017)	2017	IEEE	experts	true	phone operator	static	2D flow map, 2D graduated symbol map, stacked chart	2D+1T	non-geospatial technique	compliant	mobility patterns	yes (2)
(Kalamaras et al., 2017)	2017	IEEE	experts	true	authorities	static	2D flow map, 2D graduated symbol map, 2D ordered network map	2D	none	compliant	congestion, accidents	yes (6)
(Riveiro et al., 2017)	2017	IEEE	experts	true	research project	static	2D flow map, heatmap, heatmap, histogram, line chart, radviz	2D+1T	non-geospatial technique	compliant	accidents, microsc. mov., anomaly detection	yes (unspecified)
(Gomes et al., 2017)	2017	IEEE	experts	simulated	simulated	static	2D flow map	2D	animation	not compliant	congestion	yes (1)
(Zhang and Wang, 2017)	2017	IEEE	experts, citizens	true	transport service	static	2D dot map, 2D flow map, 2D graduated symbol map, bar chart, circle packing, donut chart, heatmap	2D+nT	none	compliant	public transportation use	no
(Baskaran et al., 2017)	2017	IEEE	experts	true	private company (not in the transport sector) (taxi)	static	2D flow map	2D	flatten (color)	not compliant	accessibility/travel time	no

Table E.16: Primary studies reviewed with the information extracted for the six SRQ (6/10).

Ref.	Year	Publish.	Target users	Data realness	Data source	Data availability	Visualization techniques	Architecture	Time representation	Compliance to mantra	Domain	User study (# partic.)
(Nagel et al., 2017)	2017	IEEE	citizens	true	authorities	static	2D flow map	2D	animation, flatten (color, size)	compliant	microsc. mov.	yes (unspecified)
(Senaratne et al., 2017)	2017	IEEE	experts	true	citizens (volunteered tracking)	static	2D choropleth map, 2D colored area map, 2D dot map, 3D flow map, heatmap, line chart, tree	2D+3D+nT	non-geospatial technique, 3D	compliant	mobility patterns	no
(Krueger et al., 2017)	2017	IEEE	experts	true	private company (not in the transport sector)	static	2D dot map, 2D flow map, heatmap, node-link diagram, stream graph	2D+nT	non-geospatial technique	compliant	mobility patterns	yes (10)
(Lu et al., 2017)	2017	IEEE	experts	true	private company (not in the transport sector) (taxi)	static	2D flow map, 2D graduated symbol map, bar chart, box plot, node-link diagram, parallel coordinates plot, stacked histogram, tree	2D+nT	non-geospatial technique	compliant	mobility patterns	no
(Leite et al., 2017)	2017	IEEE	experts	true	citizens (application)	static	2D choropleth map, 2D network map, 2D symbol map	2D	none	compliant	mobility patterns	yes (2)
(Zeng et al., 2017b)	2017	IEEE	experts	true	citizens (social media), transport service	static	2D dot map, 2D graduated symbol map	2D	symbol on GSM	compliant	mobility patterns	yes (3)
(Mešković and Osmanović, 2018)	2018	IEEE	experts	unspecified	unspecified	real-time	2D network map	2D	none	compliant	mobility patterns	no
(Buono et al., 2018)	2018	IEEE	experts	true	cameras	static	heatmap, histogram	nT	not applicable	compliant	anomaly detection	no
(Robino et al., 2018)	2018	IEEE	experts	true	unspecified	static	2D graduated symbol map, histogram	2D+1T	non-geospatial technique	compliant	parking availability	no
(Liu et al., 2018)	2018	IEEE	experts	true	authorities (taxi)	static	2D dot map, 2D flow map, 2D graduated symbol map, donut chart, heatmap, histogram, node-link diagram, scatterplot	2D+nT	non-geospatial technique	compliant	congestion, mobility patterns	yes (10)
(Caldas et al., 2018)	2018	IEEE	unspecified	simulated	simulated	static	2D flow map	2D	none	not compliant	mobility patterns	no
(You et al., 2018)	2018	IEEE	experts, citizens	true	citizens (volunteered tracking)	static	2D graduated symbol map, line chart	2D+1T	non-geospatial technique	compliant	mobility patterns	no
(Fang et al., 2018)	2018	IEEE	experts	true	authorities	static	2D flow map, 2D graduated symbol map, heatmap, line chart, scatterplot	2D+nT	non-geospatial technique	not compliant	accidents	no
(Cuenca et al., 2018)	2018	IEEE	citizens	true	authorities (open data), citizens (volunteered tracking)	static, real-time	2D dot map, 2D network map, multiset bar chart	2D+1T	none	compliant	accidents	no

Table E.17: Primary studies reviewed with the information extracted for the six SRQ (7/10).

Ref.	Year	Publish.	Target users	Data realness	Data source	Data availability	Visualization techniques	Architecture	Time representation	Compliance to mantra	Domain	User study (# partic.)
(Zhou et al., 2018)	2018	IEEE	experts	true	phone operator, transport service	static	2D flow map, 2D network map, heatmap, histogram, multiset bar chart, radar chart	2D+nT	non-geospatial technique	compliant	mobility patterns	yes (2)
(Shan et al., 2018)	2018	IEEE	experts	true	cameras	static	2D graduated symbol map, 2D ordered network map	2D	none	compliant	congestion	no
(Gürdür and Sopjani, 2018)	2018	IEEE	experts	true	sensor network	static	heatmap, histogram, proportional area chart	nT	not applicable	compliant	mobility patterns	no
(You et al., 2019)	2019	IEEE	experts	true	citizens (volunteered tracking), sensor network	static	2D graduated symbol map, 3D scatterplot, bar chart, line chart	2D+nT	non-geospatial technique	compliant	parking availability	no
(Wang et al., 2019)	2019	IEEE	experts	true	phone operator	static	2D colored area map, 2D graduated symbol map, node-link diagram, radar chart	2D+nT	none	compliant	mobility patterns	no
(Lee et al., 2019)	2019	IEEE	experts	true	sensor network	static, real-time	2D flow map, heatmap, histogram	2D+nT	non-geospatial technique, animation	compliant	congestion	yes (3)
(Shamal et al., 2019)	2019	IEEE	experts	true	unspecified (taxi)	static	2D choropleth map, 2D flow map, 2D graduated symbol map, histogram	2D+1T	non-geospatial technique	compliant	mobility patterns	yes (35)
(Kong et al., 2019)	2019	IEEE	experts	true	unspecified (taxi)	static	heatmap, line chart, node-link diagram, stacked chart	nT	not applicable	compliant	mobility patterns	no
(Menin et al., 2019)	2019	IEEE	experts	true	citizens (questionnaire)	static	2D choropleth map, chord diagram, donut chart, heatmap	2D+nT	non-geospatial technique, animation	compliant	mobility patterns	yes (51)
(Luo et al., 2019)	2019	IEEE	experts	true	phone operator	static	2D graduated symbol map, heatmap, line chart	2D+nT	non-geospatial technique	compliant	mobility patterns	yes (unspecified)
(Al-Dohuki et al., 2021)	2019	IEEE	experts	true	authorities (taxi)	static	2D flow map, heatmap, histogram, line chart, stacked bar chart, stacked histogram	2D+nT	non-geospatial technique	compliant	congestion, mobility patterns	yes (8)
(Kamw et al., 2019)	2019	IEEE	experts, citizens	true	unspecified (taxi)	static	2D colored area map, 2D flow map, 2D graduated symbol map, multiset bar chart	2D+1T	none	compliant	accessibility/travel time	yes (12)
(Pi et al., 2019)	2019	IEEE	experts	true	authorities, research project (taxi)	static	2D colored area map, 2D graduated symbol map, area chart, box plot, heatmap, line chart, multiset histogram, parallel coordinates plot, scatterplot	2D+nT	non-geospatial technique	compliant	congestion	no
(Zhao et al., 2020)	2020	IEEE	experts	true	authorities (public transport)	static	2D dot map, 2D flow map, 2D graduated symbol map, 3D network map, heatmap, node-link diagram, parallel coordinates plot	2D+3D+nT	symbol on GSM, 3D	compliant	mobility patterns, anomaly detection	yes (30)

Table E.18: Primary studies reviewed with the information extracted for the six SRQ (8/10).

Ref.	Year	Publish.	Target users	Data realness	Data source	Data availability	Visualization techniques	Architecture	Time representation	Compliance to mantra	Domain	User study (# partic.)
(Homps et al., 2020)	2020	IEEE	experts	simulated	simulated	static	2D dot map, 2D network map	2D	animation	compliant	congestion	yes (1)
(Tsung et al., 2020)	2020	IEEE	citizens	true	authorities (open data)	static, real-time	2D graduated symbol map, bar chart, heatmap, line chart, pie chart, stacked histogram	2D+nT	non-geospatial technique	compliant	mobility patterns	no
(Cheng et al., 2013)	2013	Elsevier	experts	true	authorities (cameras)	static	3D flow map	3D	3D	not compliant	congestion	no
(Pensa et al., 2014)	2014	Elsevier	experts	true	transport service	static	2D flow map	2D	none	not compliant	public transportation use	no
(Kwoczek et al., 2014)	2014	Elsevier	experts	true, simulated	private company (not in the transport sector), simulated	static	2D network map, box plot, line chart	2D+nT	non-geospatial technique	not compliant	congestion	no
(Guerra-Gómez et al., 2015)	2015	Elsevier	experts	true	research project	static	bar chart, heatmap, line chart, tree	nT	not applicable	compliant	congestion	yes (10)
(Andrienko et al., 2016)	2016	Elsevier	experts	true, simulated	private company (not in the transport sector), simulated	static	2D flow map, 2D graduated symbol map, 3D flow map, line chart	2D+3D+1T	non-geospatial technique, 3D	compliant	mobility patterns	no
(Li et al., 2016)	2016	Elsevier	experts	true	transport service, unspecified (taxi)	static, real-time	2D choropleth map, 3D colored area map, 3D dot map, 3D flow map, 3D graduated symbol map, 3D network map, 3D ordered network map, line chart, multiset histogram	2D+3D+nT	non-geospatial technique	compliant	public transportation use	no
(Zeng et al., 2017a)	2017	Elsevier	experts	true	research project (volunteer tracking), transport service	static	2D graduated symbol map, bar chart, tree	2D+nT	non-geospatial technique	compliant	mobility patterns	yes (2)
(Ni et al., 2017)	2017	Elsevier	experts	true	phone operator, citizens (social media)	static	other	1T	not applicable	not compliant	mobility patterns	no
(Coppola and Silvestri, 2018)	2018	Elsevier	experts	true, simulated	citizens (questionnaire), simulated	static	2D choropleth map	2D	none	not compliant	accessibility/travel time	no
(Huang et al., 2019)	2019	Elsevier	experts	true	citizens (social media), authorities	static	2D dot map, 2D flow map, 2D graduated symbol map, 2D ordered network map, line chart, histogram, heatmap	2D+nT	non-geospatial technique	not compliant	mobility patterns	no
(Sun et al., 2019)	2019	Elsevier	experts	true	authorities (cameras)	static	2D graduated symbol map, 2D network map, stream graph	2D+1T	symbol on GSM, non-geospatial technique	compliant	mobility patterns	yes (9)

Table E.19: Primary studies reviewed with the information extracted for the six SRQ (9/10).

Ref.	Year	Publish.	Target users	Data realness	Data source	Data availability	Visualization techniques	Architecture	Time representation	Compliance to mantra	Domain	User study (# partic.)
(Zhao et al., 2019)	2019	Elsevier	citizens	true	transport service	static	2D network map, bar chart, multi-layer ring, violin plot	2D+nT	none	not compliant	public transportation use, accessibility/travel time	yes (10)
(Liu et al., 2019)	2019	Elsevier	experts	true	unspecified (taxi)	static	2D flow map, bar chart, bubble chart, heatmap, stacked histogram	2D+nT	non-geospatial technique	compliant	mobility patterns	no
(McArthur and Hong, 2019)	2019	Elsevier	experts	true, simulated	citizens (volunteered tracking), simulated	static	2D flow map	2D	none	not compliant	mobility patterns	no
(Tomasiello et al., 2020)	2020	Elsevier	experts	true, simulated	authorities, online api (Open Trip Planner), simulated	static	2D choropleth map, box plot, line chart	2D+nT	none	not compliant	accessibility/travel time	no
(Bogorny et al., 2011)	2011	Wiley	experts	true	unspecified	static	2D dot map, 2D network map	2D	none	not compliant	congestion	no
(Krüger et al., 2013)	2013	Wiley	experts	true	private company (not in the transport sector)	static	2D dot map, 2D flow map, histogram	2D+1T	non-geospatial technique, animation	compliant	mobility patterns	yes (3)
(Zeng et al., 2013)	2013	Wiley	experts	true	transport service	static	chord diagram	1T	not applicable	compliant	mobility patterns, public transportation use	no
(Poco et al., 2015)	2015	Wiley	experts	true	authorities (taxi)	static	2D flow map, 2D graduated symbol map	2D	animation	not compliant	mobility patterns, congestion	yes (unspecified)
(Zeng et al., 2016)	2016	Wiley	experts	true	transport service	static	2D flow map, 2D graduated symbol map, sankey diagram	2D+1T	non-geospatial technique	compliant	mobility patterns	yes (5)
(Adrienko and Adrienko, 2010)	2010	Snowball analysis	experts	true	authorities, citizens (social media)	static	2D flow map, 2D graduated symbol map	2D	none	compliant	mobility patterns	no
(Cheng et al., 2010)	2010	Snowball analysis	experts	true	authorities (sensors)	static	2D flow map, 2D graduated symbol map, 3D flow map	2D+3D	3D	not compliant	congestion	no
(Andrienko et al., 2011)	2011	Snowball analysis	experts	true	authorities	static	2D graduated symbol map, 3D dot map, line chart	2D+3D+1T	non-geospatial technique, 3D	compliant	congestion	no
(Wood et al., 2011)	2011	Snowball analysis	experts, citizens	true	private company (not in the transport sector), online api (government website)	static, real-time	2D flow map, 2D graduated symbol map, histogram	2D+1T	symbol on GSM, non-geospatial technique	compliant	mobility patterns	no
(Andrienko et al., 2012b)	2012	Snowball analysis	experts	true	sensor network	static	2D flow map, 2D graduated symbol map, heatmap, line chart	2D+nT	symbol on GSM, non-geospatial technique	compliant	mobility patterns	no

Table E.20: Primary studies reviewed with the information extracted for the six SRQ (10/10).

Ref.	Year	Publish.	Target users	Data realness	Data source	Data availability	Visualization techniques	Architecture	Time representation	Compliance to mantra	Domain	User study (# partic.)
(Wörner and Ertl, 2012)	2012	Snowball analysis	experts	true	transport service	static	2D graduated symbol map, gantt chart, line chart	2D+nT	non-geospatial technique	compliant	microsc. mov.	no
(Sagl et al., 2012)	2012	Snowball analysis	experts	true	phone operator	static	2D dot map, 2D graduated symbol map, 2D network map, line chart, radar chart, scatterplot, stacked histogram	2D+nT	non-geospatial technique	not compliant	mobility patterns	no
(Song and Miller, 2012)	2012	Snowball analysis	experts	true	authorities	static	heatmap	1T	not applicable	not compliant	mobility patterns	no
(Andrienko et al., 2014)	2014	Snowball analysis	experts	true	authorities	static	2D graduated symbol map, 3D flow map, stacked histogram	2D+3D+1T	non-geospatial technique, 3D	compliant	congestion	no
(Ma et al., 2015)	2015	Snowball analysis	experts	true	phone operator	static	2D colored area map, 2D dot map, 2D graduated symbol map, 3D graduated symbol map, line chart, radar chart	2D+3D+nT	non-geospatial technique, animation	compliant	mobility patterns	no
(Jiang et al., 2015)	2015	Snowball analysis	experts	true	unspecified (taxi)	static	2D graduated symbol map, heatmap, histogram, stacked area chart	2D+nT	non-geospatial technique	compliant	mobility patterns	no
(Al-Dohuki et al., 2016)	2016	Snowball analysis	experts, citizens	true	unspecified (taxi)	static	2D dot map, 2D flow map, 2D network map, heatmap, parallel coordinates plot, parallel sets, scatterplot	2D+nT	non-geospatial technique	compliant	mobility patterns, anomaly detection, congestion	yes (17)
(Lu et al., 2016)	2016	Snowball analysis	experts	true	private company (not in the transport sector) (taxi)	static	2D graduated symbol map, discrete violin plot, heatmap, histogram, scatterplot	2D+nT	non-geospatial technique	compliant	mobility patterns	yes (unspecified)
(Wu et al., 2017)	2017	Snowball analysis	experts	true	phone operator	static	2D flow map, 2D graduated symbol map, heatmap, histogram, parallel coordinates plot	2D+nT	non-geospatial technique	compliant	mobility patterns	no
(Shi et al., 2017)	2017	Snowball analysis	experts	true	private company (not in the transport sector)	static	2D choropleth map, 2D graduated symbol map, bar chart, line chart	2D+nT	non-geospatial technique	compliant	mobility patterns	yes (16)
(Pei et al., 2018)	2018	Snowball analysis	experts	true	transport service	static	2D flow map, 2D graduated symbol map, bullet chart, heatmap, line chart, radar chart, stacked chart	2D+nT	non-geospatial technique	compliant	public transportation use, congestion	no
(Tang et al., 2018)	2018	Snowball analysis	experts	true	online api (Baidu), unspecified (taxi)	static	2D choropleth map, 2D flow map, bubble chart, donut chart, heatmap, multiset bar chart, parallel coordinates plot, rose chart	2D+nT	non-geospatial technique	compliant	mobility patterns	no

APPENDIX F

List of Primary Studies on Public Displays and Citizen Participation

This appendix provides the categorization information extracted from the primary study selected in the literature review on public displays and citizen participation. A short summary of each study is included as well.

Table F.1: Primary studies reviewed with the information extracted for the six SRQ (1/6).

Ref.	**Summary**	**Interaction modality**	**Participation level**	**Participants' characteristics**	**Urban issue**	**Evaluation**	**Participation in early dev.**
(van der Laan et al., 2013)	A system supporting urban planning activities that combines a vertical and a horizontal display is proposed. The users interact with the horizontal display and the vertical one shows related indicators.	Touch, External device (touch table)	Informing	None	Environment	None	None
(Schiavo et al., 2013b)	The authors present a public display deployed at one location of the city. Its goal is to promote citizen participation in public decisions by asking citizens' opinion on various displayed questions.	External device (mouse)	Consultation (multiple-choice)	Age, Gender	Economy, Living, Mobility, Environment	Descriptive field study	Asking users (interview)
(Claes et al., 2017)	A visualization toolkit for citizens composed of several small displays is presented. It allows citizens to display the data they wish with the visualization technique of their choosing. A feature allows collecting passersby feedback on a displayed question as well.	External device (buttons)	Consultation (multiple-choice)	None	Economy	Descriptive field study	Asking users (workshop)
(Schroeter, 2012)	The authors propose a system allowing citizens to share an idea for improving their city. The ideas are then displayed on a public screen for anyone to see.	External device (mobile phone)	Consultation	Age, Gender, Residence, Previous engagement, Digital literacy, Occupation, Education level	Economy, Mobility, Living	Descriptive field study	None
(Noyman et al., 2017)	The authors present a system for supporting a workshop activity aiming at proposing location ideas for refugees accommodation in a city. The workshop welcomes citizens, who can work with three displays representing the city at different scales.	Tangible	Placation	Age, Occupation	Living	Descriptive field study	None
(Baldauf et al., 2014)	The authors study the question of opinion polling though public displays. They compare different interaction modalities used with different question types.	Touch and External device (smartphone) as equivalent	Consultation (multiple-choice)	Age, Gender	Unspecified	Descriptive field study	None

Table F.2: Primary studies reviewed with the information extracted for the six SRQ (2/6).

Ref.	**Summary**	**Interaction modality**	**Participation level**	**Participants' characteristics**	**Urban issue**	**Evaluation**	**Participation in early dev.**
(Valkanova et al., 2014)	A public display allowing citizens to share their opinion on a displayed question is presented. Citizens can give an opinion ranging from strong disagreement to strong agreement with gesture interaction. The authors compare different conditions, preserving more or less the privacy of the vote.	Body movements	Consultation (multiple-choice)	Age, Gender, Previous engagement, Occupation	Unspecified	Descriptive field study	Asking users (interview)
(Claes and Vande Moere, 2013)	The authors present a non-technological public display allowing citizens to gain local knowledge. The display integrates with the street sign encourages reflection by showing demographic information related to the street such as the percentage of students living there.	None	Informing	Age, Family situation, Occupation, Ethnicity, Local	Living	Descriptive field study	Asking users (interview)
(Mahyar et al., 2016)	The authors propose a system allowing citizens to participate in urban planning activities. The system combines a vertical and a horizontal display is proposed. The vertical display shows indicators resulting from the interaction with the horizontal display. This work carries on the research conducted by van der Laan et al. (2013).	Touch, External device (touch table)	Placation	Occupation, Expertise	Mobility, Environment, Economy, Living	Descriptive field study	Asking users (interview, question-naire, focus group)
(Taylor et al., 2012)	A voting systems allowing citizens to share their opinion is presented. Elected officials and community groups can publish questions on the display for citizens to vote.	External device (smartphone) and External device (buttons) as equivalent	Consultation (multiple-choice)	None	Living, Governance, Environment	Descriptive field study	Asking users (interview, focus group, question-naire)
(Hespanhol et al., 2015)	The authors propose a voting system allowing citizens to cast their opinion on a displayed question. Citizens can either vote with a tablet or by gesture interaction.	External device (tablet) and Body movements as equivalent	Consultation (multiple-choice)	Gender	Unspecified	Descriptive field study	None
(Steinberger et al., 2014)	The authors propose a system deployed at a bus stop allowing passerby citizens to answer a displayed question. Citizens can cast their opinion by stepping on a *yes* or *no* pressure plate.	External device (buttons)	Consultation (multiple-choice)	Age, Gender	Unspecified	Descriptive field study	None

Table F.3: Primary studies reviewed with the information extracted for the six SRQ (3/6).

Ref.	Summary	Interaction modality	Participation level	Participants' characteristics	Urban issue	Evaluation	Participation in early dev.
(Koeman et al., 2015)	A voting system in the form of multiple voting devices deployed in a street is presented. It allows citizens to share their opinion on given questions about the neighborhood. The voting results are shown on a display painted on the street pavement.	External device (buttons)	Consultation (multiple-choice)	Age, Cultural background, Local, Amount of time living in the area	Living	Descriptive field study	Asking users (interview)
(Hosio et al., 2014a)	The authors present a touch display that can be used by citizens to be informed and give feedback on a renovation project. The authors study how different forms of feedback (writing free text, choosing a smiley on an ordinal scale) can be collected through their public display.	Touch and External device (mobile phone) as equivalent	Consultation	Age, Gender	Governance	Descriptive deployment-based research, Descriptive lab study	None
(Hosio et al., 2012)	A system allowing younger citizens to give feedback to youth workers is proposed. The citizens can share their opinion by writing free text inside a thought bubble that would be superimposed on their face picture.	Touch	Consultation	Age, Gender, Local, Previous engagement	Unspecified	Descriptive field study	Asking users (interview, focus group, question-naire)
(Steins et al., 2011)	The authors propose a public display allowing citizens to convey their opinion on public issues. The display contains words that be dragged to build a text, following the metaphor of magnets on a fridge.	Touch and External device (mobile phone) as equivalent	Consultation	None	Unspecified	Descriptive field study	None
(Behrens et al., 2014)	The authors propose a system allowing passerby citizens to express their mood in the form of a smiley about local urban issues (environment, transport, safety, public space, and housing). The aggregated results are projected onto the facade of a nearby large building.	External device (buttons)	Consultation (multiple-choice)	None	Environment, Mobility, Living	Descriptive field study	Ethnography
(Claes et al., 2018)	The authors propose a system allowing citizens to gather the opinion of other citizens on questions of their choosing. This work is the continuation of (Claes et al., 2017).	External device (buttons)	Consultation (multiple-choice)	Age, Gender, Local	Living, Environment	Descriptive field study	Asking users (interview, workshop)

Table F.4: Primary studies reviewed with the information extracted for the six SRQ (4/6).

Ref.	Summary	Interaction modality	Participation level	Participants' characteristics	Urban issue	Evaluation	Participation in early dev.
(Du et al., 2020)	A system allowing citizens to participate in urban planning activities is presented. It consists in an interactive public display projected on a wall.	External device (smartphone)	Consultation	Age, Gender, Occupation, Digital literacy, Previous engagement	Living, Mobility	Descriptive lab study	None
(Hosio et al., 2015)	The authors report on a public display deployed in order to collect citizen feedback on a renovation project. Passerby citizens could interact with the system to cast their opinion. The article is a contribution that follows (Hosio et al., 2014a).	Touch	Consultation	None	Governance	Descriptive deployment-based research	None
(Du et al., 2019)	The authors present a study on using an immersive public display to engage citizens in urban planning activities. They report on user-generated gestures to to vote and comment on urban planning material.	External device (smartphone), Body movements	Consultation	Age, Gender, Digital literacy, Previous engagement, Occupation	Mobility, Economy	Experimental lab study	None
(Coenen et al., 2019a)	The presented system enables organizations and bottom-up initiatives to present locally relevant data and to collect citizens' opinion about it. Passerby citizens can vote by pushing on a button integrated to the display.	External device (buttons)	Consultation (multiple-choice)	None	Living	Descriptive field study	Asking users (workshop)
(Coenen et al., 2019b)	A system allowing citizens to express their opinion on local questions is presented. The authors study the question of the spatial arrangement of multiple displays deployed for this purpose.	External device (buttons)	Consultation (multiple-choice)	Age, Gender, Local	Living	Descriptive field study	None
(Johnson et al., 2016b)	A situated display consulting citizens on displayed issues is presented. Among others, the authors report on how questions for consultations were formed, how locations for devices were determined, and the ways in which the data collected was fed into decision-making processes. This work follows (Taylor et al., 2012).	External device (rotatory control)	Consultation	None	Mobility, Governance	Descriptive field study	None

Table F.5: Primary studies reviewed with the information extracted for the six SRQ (5/6).

Ref.	Summary	Interaction modality	Participation level	Participants' characteristics	Urban issue	Evaluation	Participation in early dev.
(Claes et al., 2016)	The authors present a public display allowing cyclists to give their they opinion on specific questions. The interaction was especially studied for cyclists.	External device (buttons, floor mat)	Consultation (multiple-choice)	Age, Gender	Mobility	Descriptive field study	Ethnography, Asking users (workshop)
(Fredericks et al., 2015)	The authors report on field studies conducted on the use of public displays for community engagement. This work is related to (Hespanhol et al., 2015).	Touch	Consultation	Age, Gender, Digital literacy	Governance, Living	Descriptive field study	None
(Koeman et al., 2014)	The proposed system allows citizens to give their opinion on local questions with voting devices. The aggregated results are then painted on the sidewalk for citizens to see. This work is related to (Koeman et al., 2015) but is earlier.	External device (buttons)	Consultation (multiple-choice)	Education level	Living, Economy	Descriptive field study	Asking users (interview)
(Fortin et al., 2014a)	A system augmented a public agora space is presented. At this place, citizens can express their opinion publicly with a microphone. The words pronounced by the speaker are projected onto a nearby building facade.	Voice	Consultation	None	Unspecified	Descriptive field study	None
(Schroeter and Houghton, 2011)	The authors propose a public display aiming at gathering citizens' ideas on ways to improve their city. These ideas are transferred to urban planners, who are also present at the display location. Citizens can submit their ideas with their smartphone using SMS or Twitter. This article discusses the same system as the one presented by Schroeter (2012)	External device (smartphone)	Consultation	Age	Living, Mobility, Governance	Descriptive field study	None
(Vlachokyriakos et al., 2014)	The authors present a low-cost public display that allows citizens to vote on printed questions by pressing on the button of their choosing.	External device (buttons)	Consultation (simplistic)	None	Mobility, Living	Descriptive field study	None
(Ananny and Strohecker, 2009)	The authors propose a public display composed of different pictures on topics such as health and urban planning. Passersby can give their opinion on the pictures of their choosing by sending an SMS.	External device (smartphone)	Consultation	Age, Local	Living, Governance	Descriptive field study	Asking users (workshop)

Table F.6: Primary studies reviewed with the information extracted for the six SRQ (6/6).

Ref.	**Summary**	**Interaction modality**	**Participation level**	**Participants' characteristics**	**Urban issue**	**Evaluation**	**Participation in early dev.**
(Golsteijn et al., 2015)	The presented system offers a playful interaction to gather people's opinion on an event about the relationship between the government, digital democracy and the public. The participants are prompted on their socio-demographic characteristics and their opinion on the event, and are rewarded with a stress ball upon completion.	External device (buttons, rotatory control, sliders, spinners), Voice	Consultation	Age, Gender, Local	Living	Descriptive field study	None
(Whittle et al., 2010)	A public display allowing citizens to give their opinion on the services of a library by voice interaction is presented. The authors compare the proposed system with traditional methods in terms of actionability of feedback and study the impact of displaying either positive or negative previous comments on the sentiment of subsequently submitted feedback.	Voice	Consultation	Age	People	Relational field study	Asking users (unspecified)
(Fortin et al., 2014b)	The authors present a public space for public expression via a microphone. The words pronounced by the speaker are projected onto a nearby building facade. The system proposed is the one discussed by (Fortin et al., 2014a).	Voice	Consultation	None	Unspecified	Descriptive field study	Ethnography

APPENDIX G

CITIZENS' EXPECTATIONS FOR PARTICIPATION IN PUBLIC E-SERVICE DEVELOPMENT

G.1 Questionnaire

Introduction			
Q1. How often do you use electronic public services (services provided online by public administrations for citizens such as Tax-On-Web, MyPension, online forms, etc.)? O Never O More than once a year O More than once a month O More than once a week O Almost every day			
Local Consideration			
Q4. Please indicate the extent to which you agree with the following statements. The electronic administration of a city includes the city website, the services and forms it provides online (e.g. driver's license), the data it makes available to the public, and its presence on social media.			
You wish the electronic public services of your city were more accessible, faster, and more integrated with other levels of authority	Totally disagree	☐ ☐ ☐ ☐ ☐	Totally agree
You would be willing to pay extra money (directly or through taxes) so that the electronic public services of your city are more accessible, faster, and more integrated with other levels of authority	Totally disagree	☐ ☐ ☐ ☐ ☐	Totally agree
You would take time to consult relevant information about your city if they were available (e.g. budget, land registry, political debates, etc.)	Totally disagree	☐ ☐ ☐ ☐ ☐	Totally agree
You would take time to use an online platform to participate in the democratic processes of your city if such a platform existed (e.g. budget-making process, political decision-making process, etc.)	Totally disagree	☐ ☐ ☐ ☐ ☐	Totally agree
In exchange for a greater time investment on your part, you would favor the use of public electronic services if it reduced your city's administrative burden	Totally disagree	☐ ☐ ☐ ☐ ☐	Totally agree
You would take time to send relevant information to your city's departments through an online platform if such a platform existed (e.g. if you notice a road problem or bulky waste)	Totally disagree	☐ ☐ ☐ ☐ ☐	Totally agree
You would take time to participate in the development of your city's electronic public services if you were given the opportunity (e.g. by communicating your requirements through interviews, by testing these electronic services	Totally disagree	☐ ☐ ☐ ☐ ☐	Totally agree

Federal/Regional Consideration								
Q5. Please indicate the extent to which you agree with the following statements. The electronic administration of a region or a country includes these entities' website, the services and forms they provide online (e.g. taxes), the data they make available to the public, and their presence on social media.								
You wish the electronic regional and federal public services were more accessible, faster, and more integrated with other levels of authority	Totally disagree	☐	☐	☐	☐	☐	Totally agree	
You would be willing to pay extra money (directly or through taxes) so that the electronic regional and federal public services are more accessible, faster, and more integrated with other levels of authority	Totally disagree	☐	☐	☐	☐	☐	Totally agree	
You would take time to consult relevant information about your region and country if they were available (e.g. budget, land registry, political debates, etc.)	Totally disagree	☐	☐	☐	☐	☐	Totally agree	
You would take time to use an online platform to participate in the democratic processes of your region and country if such a platform existed (e.g. budget-making process, political decision-making process, etc.)	Totally disagree	☐	☐	☐	☐	☐	Totally agree	
In exchange for a greater time investment on your part, you would favor the use of public services if it reduced your region's and country's administrative burden	Totally disagree	☐	☐	☐	☐	☐	Totally agree	
You would take time to send relevant information to your region's and country's departments through an online platform if such a platform existed (e.g. if you notice a road problem or bulky waste)	Totally disagree	☐	☐	☐	☐	☐	Totally agree	
You would take time to participate in the development of your region's and country's electronic public services if you were given the opportunity (e.g. by communicating your requirements through interviews, by testing these electronic services	Totally disagree	☐	☐	☐	☐	☐	Totally agree	

Private E-service Use

Q8. How often do you use social media (Facebook, Twitter, etc.)?

O Never
O More than once a year
O More than once a month
O More than once a week
O Almost every day

Q9. How often do you use electronic private services (Ebay, Amazon, PC banking, booking, etc.)?

O Never
O More than once a year
O More than once a month
O More than once a week
O Almost every day

Digital Literacy

Q12. Please indicate the extent to which you are familiar with the following computer- or Internet- related elements?

Tagging	No understanding	O	O	O	O	O	Full understanding
PDF	No understanding	O	O	O	O	O	Full understanding
Spyware	No understanding	O	O	O	O	O	Full understanding
Wiki	No understanding	O	O	O	O	O	Full understanding
JPG	No understanding	O	O	O	O	O	Full understanding
Weblog	No understanding	O	O	O	O	O	Full understanding
Cache memory	No understanding	O	O	O	O	O	Full understanding
Malware	No understanding	O	O	O	O	O	Full understanding
Phishing	No understanding	O	O	O	O	O	Full understanding

Socio-Economic Characteristics
Q13. In which age interval do you fall? O Under 20 years old O 20-29 O 30-39 O 40-49 O 50-59 O Over 60
Q14. What is your gender? O Female O Male O Other
Q15. What is the highest degree you received? O No degree O Primary school degree (until 12 years old) O Inferior secondary school degree (until 15 years old) O Superior secondary school degree (until 18 years old) O High school degree O University degree O PhD
Q16. What is your current occupation? O Student O helper O Employed O Self-employed O Unemployed O Retired
If answer to Q16 was [Employed] Q17. Do you work in a public administration? O No O Yes, at a local level O Yes, at a provincial level O Yes, at a regional level O Yes, at a federal level O Yes, at a European level

G.2 Statistic Tests

Table G.1: Statistic tests details (1/2)

Relationship	Statistic value and significance level
R1	loc: K-S = 1.702, p = 0.006
	fed: K-S = 1.497, p = 0.023
R2	loc: K-S = 1.809, p = 0.003
	fed: K-S = 1.388, p = 0.042
R3	loc: K-S = 1.367, p = 0.048
R4	loc: J = 6620.000, std. J = -2.931, p = 0.003
	fed: J = 6409.000, std. J = -3.415, p = 0.001
R5	loc: J = 6640.000, std. J = -2.879, p = 0.004
	fed: J = 6506.500, std. J = -3.204, p = 0.001
R6	fed: J = 7017.500, std. J = -1.979, p = 0.048
R7	loc: H = 14.636, p = 0.002
	fed: H = 10.771, p = 0.013
R8	loc: H = 11.475, p = 0.009
	fed: H = 13.427, p = 0.004
R9	loc: J = 9206.500, std. J = 5.639, p = 0.000
	fed: J = 9218.500, std. J = 5.927, p = 0.000
R10	loc: J = 8055.000, std. J = 2.179, p = 0.029
R11	loc: J = 8328.500, std. J = 2.691, p = 0.007
	fed: J = 8079.000, std. J = 3.644, p = 0.000
R12	loc: J = 9655.500, std. J = 5.453, p = 0.000
	fed: J = 9192.000, std. J = 4.626, p = 0.000
R13	fed: J = 8706.500, std. J = 2.140, p = 0.032
R14	loc: J = 8344.000, std. J = 4.208, p = 0.000
	fed: J = 8763.500, std. J = 4.825, p = 0.000
R15	loc: J = 9856.000, std. J = 5.028, p = 0.000
	fed: J = 9180.500, std. J = 4.199, p = 0.000

loc – local government level
fed – federal/regional government level
p – p-value
K-S – Kolmogorov-Smirnov test statistic
J – Jonckheere-Terpstra test statistic
std. J – standardized Jonckheere-Terpstra test statistic
H – Kruskal-Wallis test statistic

Table G.2: Statistic tests details (2/2)

Relationship	**Statistic value and significance level**
R16	loc: J = 8661.000, std. J = 4.463, p = 0.000
	fed: J = 8122.500, std. J = 3.179, p = 0.001
R17	loc: J = 7959.000, std. J = 2.743, p = 0.006
	fed: J = 8042.500, std. J = 3.049, p = 0.002
R18	fed: J = 7662.000, std. J = 2.040, p = 0.041
R19	loc: J = 8337.000, std. J = 3.744, p = 0.000
	fed: J = 8332.000, std. Z = 3.714, p = 0.000
R20	loc: J = 8164.500, std. J = 3.130, p = 0.002
	fed: J = 7764.500, std. J = 2.260, p = 0.024
R21	loc: J = 4792.000, std. J = 2.517, p = 0.012
	fed: J = 4635.500, std. J = 2.049, p = 0.040
R22	loc: J = 4819.500, std. J = 2.561, p = 0.010
	fed: J = 4996.500, std. J = 3.112, p = 0.002
R23	fed: J = 7033.500, std. J = 2.523, p = 0.012
R24	loc: J = 7116.000, std. J = 2.678, p = 0.007
	fed: J = 7142.000, std. J = 2.760, p = 0.006
R25	fed: J = 6890.500, std. J = 2.114, p = 0.035

loc – local government level
fed – federal/regional government level
p – p-value
K-S – Kolmogorov-Smirnov test statistic
J – Jonckheere-Terpstra test statistic
std. J – standardized Jonckheere-Terpstra test statistic
H – Kruskal-Wallis test statistic

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