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Public Displays and Citizen Participation: A Systematic Literature Review and Research Agenda

Antoine Clarinval, Anthony Simonofski, Benoît Vanderose, and Bruno Dumas

Abstract

Purpose - The objective of this research is to study how current research reports reflect on using public displays in the smart city. In particular, it looks at the state of the art of this domain from two angles. On the one hand, it investigates the participation of citizens in the development of public displays. On the other hand, it aims at understanding how public displays may foster citizen participation in addressing urban issues. Its goal is to provide (1) a literature review of this field, and (2) a research agenda.

Design/methodology/approach - A systematic literature review (SLR) was conducted following a thoroughly detailed protocol. It surveys 34 recent papers through multiple aspects, including interaction modality, level of participation, socio-demographics of participating citizens, topic of participation, evaluation of the display, and participation of end-users in the early development stages of the display. Then, a research agenda informed by the results of the SLR is discussed in light with related literature.

Findings - The SLR showed that further research is needed to improve the involvement of citizens in the early stages of the development of public displays, broaden the spectrum of citizen participation achieved through public displays, integrate public displays with other means of participation, and handle the changing urban context to improve the participation experience.

Originality/value - Previous literature reviews have been conducted in the field of public displays, including one specifically related to citizen participation. However, they have emphasized the technological aspects of public displays and omitted other essential aspects. This article aims at addressing this gap by conducting a literature review including also non-technological perspectives such as socio-demographics and participation in development, complementing other works.

Keywords: Citizen participation, Public display, Systematic literature review

1. Introduction

Public displays are becoming more and more commonplace in cities. They usually serve advertising purposes or show locally relevant data such as transportation schedules or upcoming events and are in most cases non interactive (Thiel, 2015). The use of public displays for other purposes such as providing services to citizens (Hosio *et al.*, 2016) has also been investigated (Kostakos and Ojala, 2013).

An application of public displays that received substantial attention recently is citizen participation (Du *et al.*, 2017), which can be defined as the different roles (Simonofski *et al.*, 2018) of citizens in government decision-making processes (Arnstein, 1969). The fact that public displays can be integrated in the urban landscape of a city (thus, contextualizing the displayed information) and that they can allow multiple users to interact together makes them a suitable solution for citizen participation (Vande Moere and Hill, 2012).

Previous contributions have reviewed literature on public displays, including their use for citizen participation purposes. However, some essential aspects of the field were not explored by these works, such as the socio-demographic characteristics of the participating citizens. Also, how citizens participate in the development of public displays, in other words how public displays are developed by citizen participation, remains largely unexplored. In order to fill these gaps, a systematic literature review (SLR) following the guidelines prescribed by Kitchenham and Charters (2007) and Petersen *et al.* (2008) was conducted. This survey studies the question of public displays *for* citizen participation, as well as public displays *by* participation. Thus, it reviews research works from several perspectives relating to these two aspects, including interaction modality, participation level, characteristics of participating citizens, topic of participation (referred to as “urban issue”), participation of end-users in the evaluation, and participation in earlier development stages. In total, 34 contributions were reviewed following this 6-perspective scheme.

Then, a research agenda informed by the results of the SLR is proposed. It discusses four research directions worthy of more attention from researchers. First, large-scale methods could be used to improve the involvement of citizens in the development of public displays. Second, user interaction techniques and display orientation could be levers to expand the spectrum of participation achieved through public displays. Third, more attention should be given to the socio-demographics of the effective users of public displays to ensure that public displays integrate efficiently into the ecosystem of participation methods. Fourth, adaptive public displays are proposed as a solution to handle changes in the urban context and the users.

The remaining of this paper is organized as follows. In Section 2, a brief background on public displays for citizen participation research is presented. Previous literature reviews on public displays are discussed as well. In Section 3, the review protocol that guided the SLR is detailed. The results of the SLR are reported in Section 4. Section 5 presents the research agenda informed by the results of the SLR. The threats to validity of the SLR are discussed in Section 6. Section 7 closes the paper with concluding remarks.

2. Related work

2.1. Public Displays and Citizen Participation in Smart Cities

Recently, smart cities have emerged as a solution to the modern challenges faced by cities such as road congestion and the environmental impact of the city activities (Caragliu *et al.*, 2011). In practice, this has been reflected by numerous technological products pushed by cities and companies in an attempt to solve these issues. However, in many instances, this proved unsuccessful as

cities failed to take into account the specificities of their territory (Dameri, 2014). Instead, some authors recommend to involve citizens and use their needs as starting point of the smart city before considering any use of technology (Hollands, 2008; van Velsen *et al.*, 2009; Linders, 2012), as the challenges technology aims to meet are those faced daily by the citizens. In this context, the use of technology to empower citizens is also suggested in the literature (Cugurullo, 2013; Kitchin, 2014).

This participative orientation of smart cities has become increasingly popular in practice and research. As a result, many initiatives have emerged in order to allow citizens to make their voice heard in the smart city on issues relating to their life in the city (referred to as “urban issues” in the remaining of the paper) through various participation methods (Simonofski *et al.*, 2019a), and this has intensified the research on public displays enabling citizen participation. For instance, public displays have been used to engage citizens on issues such as politics (Steinberger *et al.*, 2014), energy consumption (Valkanova *et al.*, 2013), and renovation projects (Hosio *et al.*, 2014). Indeed, the ability of public displays to support multi-user interaction, to show and collect situated information (Vande Moere and Hill, 2012), and to spark discussion (Brignull and Rogers, 2003) makes them a good candidate method to support citizen participation in smart cities. Moreover, the interaction with public displays is by nature opportunistic. In other terms, citizens do not go in the urban environment with the explicit goal to interact with a public display. This is an advantage that public displays as a citizen participation method have over other frequently used methods such as questionnaires, citizen meetings, or online participation platforms accessible from a personal computer. Indeed, with these methods, participating requires an explicit action, such as logging in to a website or travelling to a specific location. Thus, they tend to attract only a restrained part of the population, which is engaged in citizen participation beforehand. On the contrary, the opportunity to participate with a public display is something citizens stumble upon. 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.*, 2016).

However, deploying a public display that is able to collect such an 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), and interaction blindness (Ojala *et al.*, 2012). 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.*, 2014; Niiro *et al.*, 2019). All these factors coming into play also makes the evaluation of public displays challenging, as environment-related dynamics need to be carefully studied (Hornecker and Nicol, 2012; Claes *et al.*, 2015).

2.2. Previous Surveys on Public Displays

Over the last years, several surveys have been published to study how users interact with public displays. Five of them are brought up and discussed below.

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.

Four years later, 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.

The same year, 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.

More recently, 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* (projection or monitor), *display setup* (vertical, horizontal, diagonal, floor), *interaction modality* (touch, external devices, tangible objects, body movements), *application purpose* (goal of the display), and *location* (location where the display is set up). 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.

Closer to the scope of the study presented in this article is the survey conducted by Du *et al.* (2017). The authors are interested in 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 (denoted as the *political context*), 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.*, 2018) processes remain largely unexplored.

3. Methodology

This section details the review protocol that guided the survey. It was defined in line with the systematic literature review guidelines prescribed by Kitchenham and Charters (2007) and Petersen *et al.* (2008). The 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 4 (*reporting the review*), are successively discussed.

3.1. Planning the Review

3.1.1. Research Questions

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).

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 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 survey, the four interaction modalities listed by 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.

In this paper, 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. *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. 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.

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 survey, six categories of urban issues are considered, following the six smart city dimensions listed by Giffinger and Gudrun (2010). *Smart economy* relates to employment and companies (e.g. entrepreneurship). *Smart people* is related to the human capital (e.g. citizens’ qualifications). *Smart governance* concerns the public services provided to citizens (e.g. e-government). *Smart mobility* relates to the transportation infrastructure (e.g. accessibility, sustainable mobility). *Smart environment* refers to the environmental impact of the city (e.g. pollution, waste management). Lastly, *Smart living* relates to the well-being of citizens broadly speaking (e.g. social cohesion, security, health). Giffinger’s 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 by Alt *et al.* (2012), who list 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 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 statis-

tical significance tests. In this survey, this twofold characterization (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.* (2017) were considered, namely *interviews and group discussions*, *representation in project team*, *workshops*, *surveys*, *dedicated software*, *social media*, *innovation ecosystem*, and *prototyping*.

Table 1 summarizes the sets of categories for each SRQ.

Table 1 should appear here.

3.1.2. Search for Primary Studies

As the SLR presented in this paper consists of a desk work using secondary data analysis, relevant primary studies on the topic of public displays were collected. In order to do so, a search was performed on three digital libraries, namely ScienceDirect, IEEEExplore, and ACM Digital Library. The choice of ACM Digital Library and IEEEExplore was motivated by the popularity of ACM and IEEE among researchers who work in computer science related domains. 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. 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. A snowball analysis (i.e. a search on the selected articles' bibliographies) was conducted to collect additional articles and therefore ensure a more complete coverage. After aggregating all the relevant articles, a search was performed on Google Scholar as a final check of coverage completeness. Figure 1 presents a visual overview of the article search process.

The search string applied to the chosen digital libraries was structured following the PICOC (Population, Intervention, Comparison, Outcomes, Context) framework proposed by Petticrew and Roberts (2008). 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.* (2017), 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 search query 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 Coproduction OR Coproduction OR Debate OR Empower OR Empowerment OR Participative OR Civic OR Poll OR Vote OR Opinion OR Citizen OR Awareness)

The search string was applied on the *title* and the *keywords* field of the articles, alike for the four selected digital libraries. As for the articles collected through the snowball analysis and those extracted from Du *et al.* (2017), compliance to the search terms was not checked, as their presence in the bibliography of a relevant article serves as initial filter instead. Rather, their relevance was determined solely by the criteria discussed below.

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 survey. 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:

1. **Articles not written in English.**
2. **Duplicated articles.**
3. **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, in the smart cities field, a previous survey (Ojo *et al.*, 2016) showed that the growth of the 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 body of research in the field.
4. **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 and are not included in the body of research surveyed in this study.
5. **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.

3.2. Conducting the Review

Initial search. In total, the search on ScienceDirect, ACM Digital Library, and IEEEExplore yielded 623 papers congruent with the search terms. After analyzing their meta-information and abstract,

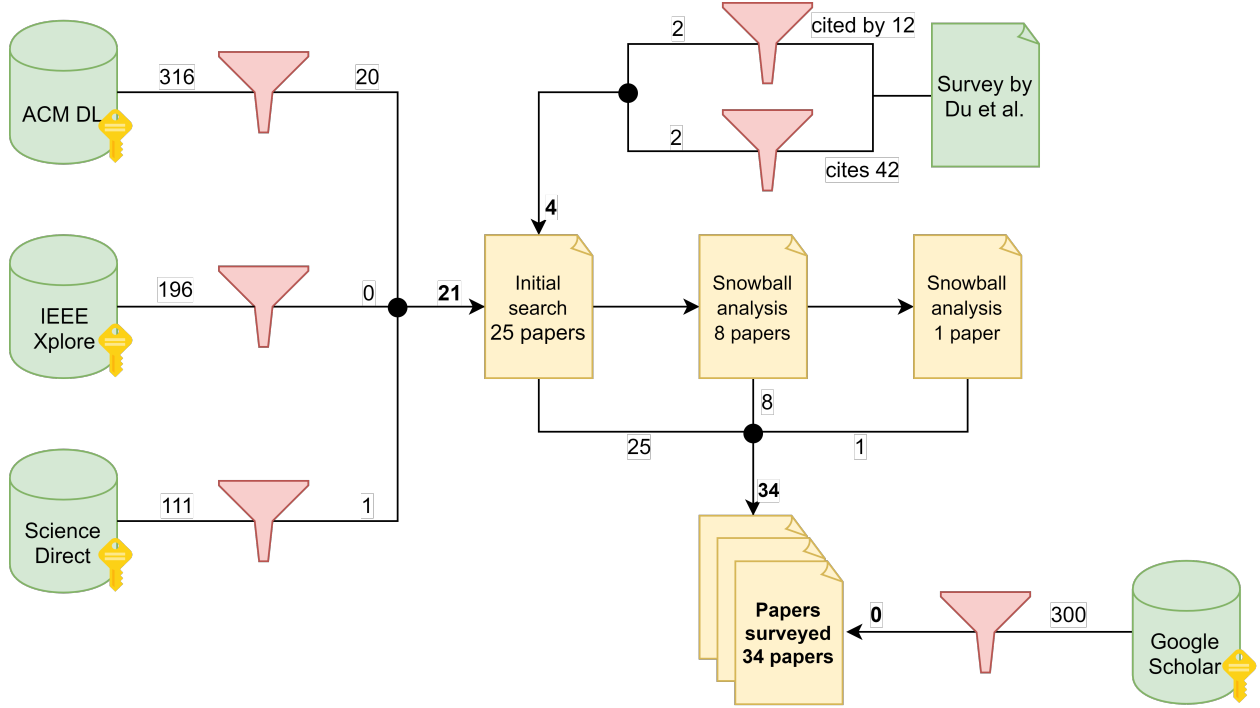


Figure 1: Methodology followed to conduct the review. First, the keyword search (indicated by the key symbol) was performed on ACM DL, IEEE Xplore, and Science Direct. The coverage was completed by analyzing the papers citing and cited by Du *et al.* (2017). 25 relevant articles were extracted. After 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.

21 articles passed the inclusion and exclusion criteria check. The distribution per digital library is shown in Table 2. It can be observed that the precision (i.e. 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%, the precision of IEEE Xplore and ScienceDirect is much lower. 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 survey. These are articles about *social media* use and *public opinion* analysis. For IEEE Xplore, the search returned many articles discussing *public opinion* analysis systems, *collaborative ubiquitous* systems and software *architecture*. 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, 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 initial search yielded a total of 25 articles, 21 extracted from the search on digital libraries and 4 from Du *et al.* (2017).

Table 2 should appear here.

Snowball analysis. The snowball analysis conducted on the 25 articles returned by the initial search 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 surveyed 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.

Google Scholar coverage check. 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.

Article 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.

The 34 publications constituting the survey body are listed in Table 3. Their pertaining classification information are available as supplementary material to this paper.

Table 3 should appear here.

3.3. Reporting the Review

In the subsequent section of this paper, the findings drawn from the survey are presented by successively addressing the six SRQ defined earlier. Section 5 discusses four future research directions informed by the results of the SLR.

4. Results

This 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.

4.1. 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 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 (rotatory controls, tablet, mouse, etc.) 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.*, 2014). 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.

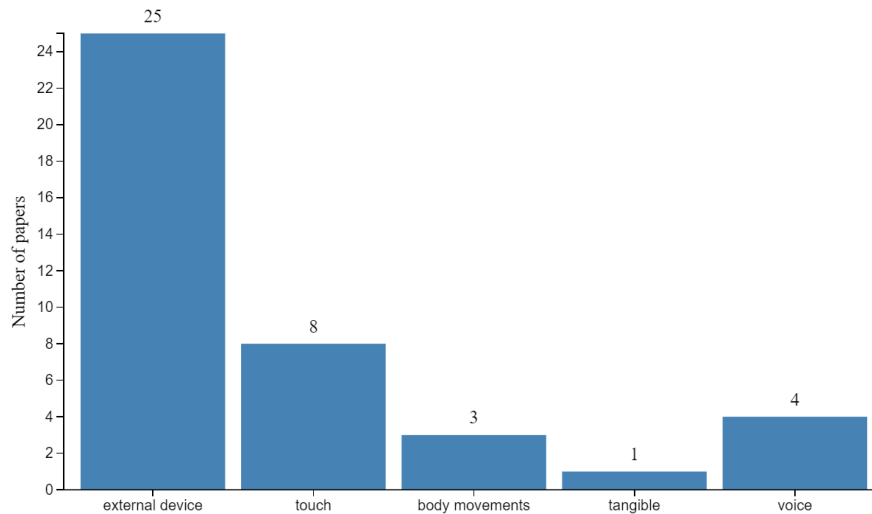


Figure 2: Interaction modalities offered by public displays (SRQ 1)

4.2. Level of Participation Achieved (SRQ2)

Only three of the eight levels defined by Arnstein are represented in the surveyed papers (see Figure 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 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.*,

2014), and online publication of accepted ideas (Noyman *et al.*, 2017). Fredericks *et al.* (2015) reported that the collected citizens’ opinion drove decisions, but the article does not mention whether citizens were informed of that.

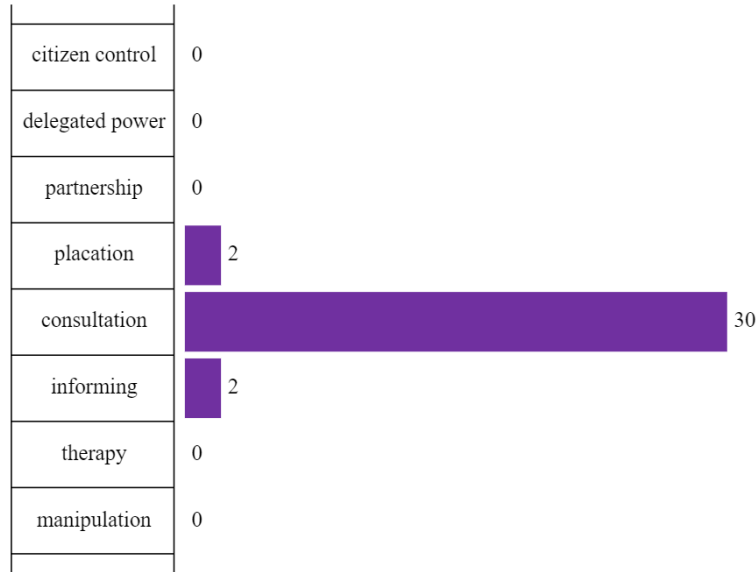


Figure 3: Participation levels supported by public displays (SRQ 2)

4.3. Socio-Demographics of Participants (SRQ3)

Overall, few articles report extensively on socio-demographics, 11 articles not discussing any. Table 4 shows the socio-demographic characteristics reported in the surveyed articles.

From Table 4, it can be observed that 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.

Table 4 should appear here.

4.4. 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 by 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 were not reported by the authors, the urban issue was labelled as *Unspecified*. This concerns 8 of the 34 articles.

The second observation is the prominence of the living urban issue, which is tackled by 18 displays (see Figure 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.

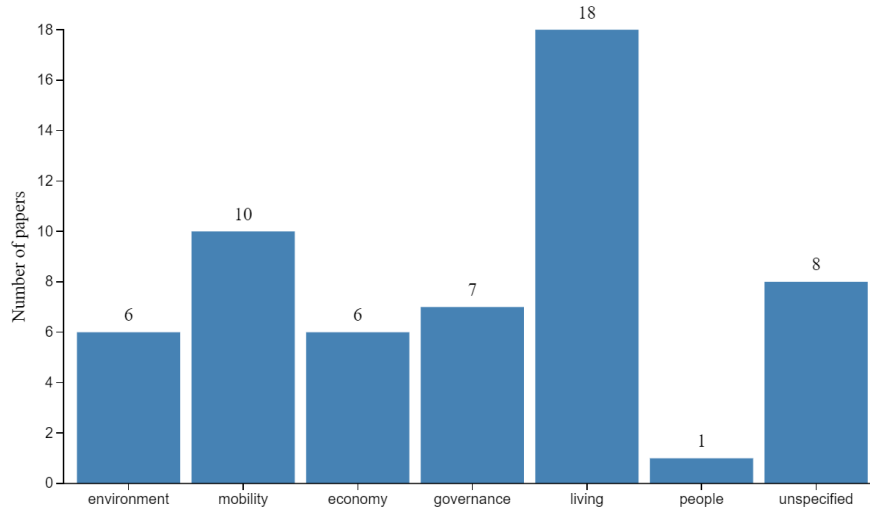


Figure 4: Urban issues tackled by public displays (SRQ 4)

4.5. 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, Hosio *et al.* (2014) 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 5).

Table 5 should appear here.

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.

4.6. 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.* (2017). 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, labelled 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).

5. Discussion: Toward a Research Agenda

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

5.1. 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* (12), *workshops* (5), and *surveys* (3).

Focus groups, interviews, and workshops allow participation in development on a small scale (Simonofski *et al.*, 2017), 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 this 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 favoring 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 would submit questions to the citizenry more aligned with their current concerns.

5.2. 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 leveraged 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.* (2014) 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.*, 2011), 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 *et al.*, 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).

5.3. 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 in (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.* (2019b) 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.

5.4. Research Direction 4: Handling a Changing Context

This research directions 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).

In order to identify opportunities for adaptive public displays, a starting point is to understand the factors that drive passerby citizens to interact with a public display (*motivators*) or to continue on their way without interacting (*barriers*), as well as how they vary according to citizens’ characteristics. Examples of well-known motivators and barriers include the honeypot effect (Brignull and Rogers, 2003), the social awkwardness (Brignull and Rogers, 2003), and the display blindness (Müller *et al.*, 2009). However, the link between these and citizens’ characteristics remains unstudied, and more motivators and barriers can be extracted from the surveyed field studies. It would also be valuable to confront the motivators and barriers identified in the public display literature to related works on motivators to citizen engagement such as (Wijnhoven *et al.*, 2015), (Holgersson and Karlsson, 2014), and (Naranjo-Zolotov *et al.*, 2019).

6. Threats to validity

The survey presented in this article has threats to its validity, both in its planning and its carrying. They are detailed in this section.

6.1. Planning the Review

Following the PICOC framework described by Petticrew and Roberts (2008), 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.

Second, 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).

Third, 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.

6.2. Conducting the Review

First, the relevancy 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.

Second, 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.

7. Conclusion

The goal of the survey presented in this paper was to review the literature on public displays as a citizen participation method and to define a research agenda for the field. In particular, the literature review aims at addressing two questions: the impact of public displays on citizen participation (*public displays for citizen participation*), and the involvement of citizens in their development (*public displays by citizen participation*).

In order to achieve this goal, a systematic literature review was conducted, following a rigorous review protocol defined in line with the methodological guidelines provided by Kitchenham and Charters (2007) and Petersen *et al.* (2008). In total, 34 articles were analyzed from both the public display *for participation* and *by participation* sides: interaction modalities, level of participation achieved, socio-demographics of participating citizens, urban issues tackled, user evaluation, and participation of citizens in early stages of the development.

The aggregated information collected on the reviewed sample allowed informing an agenda of four research directions. First, the potential of large-scale participation methods to improve user involvement in the early stages of the development of public displays. Second, the lack of

support for higher participation levels where citizens can have a stronger impact. Third, the lack of attention given to the socio-demographic characteristics of the effective users of public displays, which are however essential to ensure an efficient ecosystem of participation methods. Fourth, adaptive public displays as a solution to handle changes in the urban context while offering the best possible participation experience.

However, as discussed in Section 6, the survey has limitations in its planning and conduct. They were alleviated by various actions such as snowball analysis and having multiple researchers reviewing each article.

Overall, the contributions of this paper are the following. First, a systematic literature review is provided on public displays for and by citizen participation. Second, a research agenda informed by the results of the review is discussed in light with related literature.

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Tables

Table 1: Classification scheme used to extract information from the surveyed articles

Public displays <i>for</i> 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 <i>by</i> 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

Table 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	Precision
ScienceDirect	111	1	0.9%
ACM Digital Library	316	20	6.3%
IEEEExplore	196	0	0%
Total	623	21	3.4%

Table 3: Surveyed articles listed by search method

Search method	Articles
ScienceDirect	(Noyman <i>et al.</i> , 2017)
ACM Digital Library	(van der Laan <i>et al.</i> , 2013)(Schiavo <i>et al.</i> , 2013b)(Claes <i>et al.</i> , 2017)(Schroeter, 2012)(Baldauf <i>et al.</i> , 2014)(Valkanova <i>et al.</i> , 2014)(Claes and Vande Moere, 2013)(Mahyar <i>et al.</i> , 2016)(Taylor <i>et al.</i> , 2012)(Hespanhol <i>et al.</i> , 2015)(Steinberger <i>et al.</i> , 2014)(Behrens <i>et al.</i> , 2014)(Claes <i>et al.</i> , 2018)(Coenen <i>et al.</i> , 2019b)(Coenen <i>et al.</i> , 2019a)(Koeman <i>et al.</i> , 2014)(Fortin <i>et al.</i> , 2014a)(Fredericks <i>et al.</i> , 2015)(Johnson <i>et al.</i> , 2016)(Claes <i>et al.</i> , 2016)
IEEEExplore	none
Extracted from (Du <i>et al.</i> , 2017)	(Hosio <i>et al.</i> , 2014)(Ananny and Strohecker, 2009)(Du <i>et al.</i> , 2020)(Du <i>et al.</i> , 2019)
Snowball analysis 1	(Steins <i>et al.</i> , 2011)(Hosio <i>et al.</i> , 2012)(Koeman <i>et al.</i> , 2015)(Schroeter and Houghton, 2011)(Vlachokyriakos <i>et al.</i> , 2014)(Golsteijn <i>et al.</i> , 2015)(Whittle <i>et al.</i> , 2010)(Hosio <i>et al.</i> , 2015)
Snowball analysis 2	(Fortin <i>et al.</i> , 2014b)
Google Scholar	none

Table 4: 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

Table 5: 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