Technical Infrastructure to Support Public Value Co-creation in Smart City

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Abstract: *Background:* In recent years, with the rapid advancement of the ICT tools, such as social media and IoT, the citizen participation channels have been varied, leading to the need to construct the technical means that integrate these participation channels for public value co-creation. *Purpose:* In this paper, we aim to support decision-makers and policymakers by designing technical infrastructure to support the co-creation of public value in a smart city, which could be seen as a good alternative for public institutions suffering to create value cooperatively with citizens. *Design/methodology/approach:* We employ the citizen participation model for public value co-creation proposed by our previous work as a theoretical framework and adopt Design Science Research Framework proposed by March and Smith. *Findings*: We build the technical infrastructure to support public value co-creation. *Research limitations:* Despite the validation of technical infrastructure demonstrated through comparative analysis, we do not argue the completeness of our artefact. In the specific implementation process of the infrastructure, it is possible to occur various challenges, in particular, technical challenges. *Practical implications:* We explain how to harness the synergy between government-led and citizen-led participation, which is the ubiquitous emerging social phenomenon in smart cities. *Originality/value:* Our artefact supports comprehensively two approaches to online participation — government-led and citizen-led participation, including social media and IoT-based participation, which could be considered as the primary innovative approaches for governments to solicit citizens' opinions and examine behavioral information for the objective of the data-driven policy-making process.

Keywords: Technical Infrastructure, Co-creation of Public Value, Citizen-Led Participation, Internet of Things (IoT), Social Media

1. Introduction

In a general sense, a smart city refers to a place where ICT is combined with infrastructure, architecture, everyday objects, and people to address socioeconomic and environmental challenges [1]. The goal of a smart city initiative is not simply to obtain economic benefits by introducing ICT to urban affairs but to positively impact the citizens' quality of life by implementing democratic principles in city governance [2]. This new orientation makes the actual objective of a smart city become public value creation understood as the value created through the creation and implementation of technology and service that adequately utilize the opportunities in a city, address social challenges, and achieve policy goals [3].

The interaction of technological and social innovations and the increasing demands of citizens to participate in the public policymaking process and public service provision lead to changing from top-down approach that a government led to a cooperative approach among various stakeholders including government and citizens. This approach enables citizens to become co-creators rather than mere beneficiaries of public policy and public service provision.

Government "owned" digital platforms for public value co-creation have emerged as a result of the efforts by local and national governments to utilize ICT for public value co-creation. Citizen participation in a government-led platform has been conducted in such a way that invited citizens to participate in discussions or enabled citizens to

express their ideas about them after the government presents the social issues that interested the public on the platform. Despite the government's striving, the approach was not much successful, with one of the most important causes being the lack of citizen participation.

Meanwhile, emergence of new ICT tools, such as social media and Internet of Things (IoT), has formed a new paradigm in co-creation of public value. In social media, citizens voluntarily discuss the various issues they are interested in without government intervention, and it has become a new dimension of citizen online participation [4]. In addition, citizens contribute to extracting insights for value creation by using the city infrastructure that IoT is embedded. In particular, IoT-based participation could take a big step toward improving democracy in urban governance by allowing special groups of residents, such as minors and temporary residents, who were previously unable to participate in city affairs due to the various constraints including the digital divide, to be included in the value creation process [5]. Two approaches to online participation — social media and IoT could be considered as the primary innovative mediums for governments to solicit citizens' opinions and examine behavioral information for the objective of the data-driven policy-making process and change the expected roles of citizens [5].

Considering that citizen online participation mediated by social media and IoT is voluntarily conducted by residents without government intervention, and a government extracts insights for value creation from the processes, they are considered citizen-led participation [6]. According to Macintosh et al., government-led and citizen-led participation work in synergy [4].

Against this background, we believe that the ICT system to harness the synergy between the two approaches of citizen online participation, that is, government-led and citizen-led participation, for the public value co-creation needs to be constructed. A few researchers have considered the ICT system to harness simultaneously government-led and social media-based participation or social media and IoT in the public setting [7, 8], but it is deemed that the authors overlook IoT that is a crucial tool to support citizen participation in a smart city [7] or the synergy between government-led and citizen-led participation [8] and, moreover, its theoretical basis is insufficient. Considering that the ICT system to support public value co-creation is a socio-technical system, an insufficient theoretical basis is a crucial gap. To bridge the gaps, in this paper, we focus the following research question.

RQ: How can technology support the synergy between government-led and citizen-led participation for the co-creation of public value in the smart city setting?

We believe that an approach to tackling our research question is to design the technical infrastructure to harness government-led and citizen-led participation, including social media and IoT. To construct the technical infrastructure supporting the synergy between the two approaches of citizen online participation, we employ a citizen participation model for public value co-creation proposed in our previous work as a theoretical framework and the Design Science Research Framework (DSRF) proposed by March and Smith [9] as our approach. The validity of the designed artefact is examined through comparative analysis.

The remainder of this paper is as follows:

The second section explores the theoretical framework for building the technical infrastructure to support public value co-creation. The third section describes the approach adopted in this work. The fourth section design the technical infrastructure. The fifth section examine the validity of our artefact through a comparative analysis. Finally, the discussion and conclusion are given.

2. Theoretical Framework

Harnessing citizen-led approaches for public value co-creation in the smart city setting makes the change of traditional and hierarchical relationships between government and citizens accelerate, leading to the emergence of a new social structure of value co-creation, and, eventually, promoting citizen empowerment in city governance [5]. Motivated by the need to reveal the mechanism of the interface change between government and citizens in the public value co-creation resulting in the emergence of participation means such as social media and IoT, and identify the governmental capabilities to launch a new social structure of public value co-creation, in the previous research, we have proposed a citizen participation model for the co-creation of public value in a smart city (reference removed for review). Drawing on Gidden's theory of structuration [10] and dynamic capability theory [11] including dynamic risk management capability [12], this new analytical framework simultaneously includes two approaches to online participation — social media and IoT, which could be considered as the primary innovative mediums for governments to solicit citizens' opinions and examine behavioral information for the objective of the data-driven policy-making process. More specifically, we attempted to argue that the proposed model depicting citizen-led participation, including social media and IoT-based participation should be referred to as a new form of the co-creation process of public value. Based on the dynamics between the two analytical levels of public administration – the macro level and the meso-level [13]– we have elucidated the dynamics between the two theories and proposed a citizen participation model for public value co-creation that harness the synergy between government-led participation and citizen-led participation [4]. Eventually, an integrated analytical framework derived from the theory of structuration and dynamic capability theory is demonstrated to acknowledge the modified roles of citizens in the digital governance setting (Figure 1).

In the proposed model, the two pillars of citizen online participation, that is, government-led and citizen-led participation, are harnessed together to support the dynamic distribution of allocative and authoritative resources between

citizens and decision-makers in public value creation. Participants exercise their agency by participating in public value creation using allocative resources such as government "owned" online participation platforms, social media, and

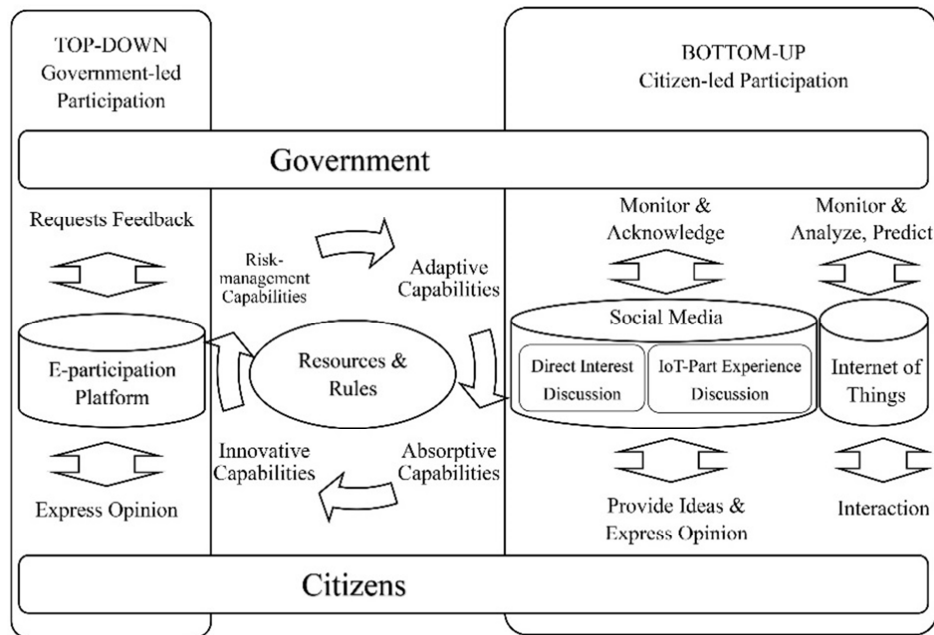IoT, and authoritative resources based on the acknowledgment of a government on the citizens' knowledgeability.

Figure 1. *Citizen participation model for public value co-creation.*

Citizen participation for public value co-creation is guaranteed for its continuity and significance through dynamic capabilities that a government has built. We have identified the following governmental capabilities to operate a new social structure of public value co-creation: adaptive capability; absorptive capability; innovative capability; risk management capability (Reference removed for peer-review). The adaptive capability corresponds to the governmental capability to redistribute allocative resources (e.g., dedicated co-creation platform, social media, IoT) and authoritative resources (e g., agenda-setting authority), and renew rules accordingly. The absorptive capability consists of a continuous monitoring process of participation resources to extract insights underlying policymaking and/or public service delivery and integrate data from social media and IoT; these link in turn to policy agenda formation based on governmental acknowledgment of the citizens' knowledgeability. Innovative capability is the governmental capability to provide new participation channels other than the existing participation tools. In the public value co-creation setting, risk management capability is, first, a continuing revaluation and prioritization of factors that could hurt citizen motivation to participate; the second pillar is risk resiliency; the third pillar is the notification to citizens of the outcome treating risks. The four capabilities mentioned above enable continuous and recursive communication among citizens and between government and citizens in public value creation and ensure citizens exercise their agency in city governance.

3. Approach

In this section, we discuss the approach — the Design Science Research Framework (DSRF) [9] — to designing the technical infrastructure for public value co-creation. We adopt the DSRF to the specific needs of technical infrastructure design. The design of our artefact consists of the following phases:

P1) Eliciting the infrastructure requirements — based on citizen participation model for the co-creation of public value [5], we elicit the requirements of our artefact. The process is achieved in two sub-phases. The first sub-phase involves determining the socio-technical and organizational capabilities (Table 1) required for the infrastructure design, while the second consists of refining these capabilities into concrete system requirements (Table 2).

P2) Gap investigation based on mapping related ICTs — we explore existing achievements that could support the requirements elicited in Phase 1. Following the mapping, we detail specific gaps identified with respect to the realization of our artefact (Table 3).

P3) Design of the technical infrastructure for pubic value co-creation — based on the requirements and gaps identified in Phases 1 and 2, we develop the key design elements for the technical infrastructure for public value co-creation. The resulting model addresses the integration of government- and citizen-led participation as a synergistic process.

P4) Feasibility of the infrastructure designed – in this phase, we discuss the possibility of implementing the technical infrastructure for public value co-creation designed

by existing ICTs.

P5) Validity of the technical infrastructure – in this phase, we examine the validity of our artefact through comparative analysis.

4. Design of Technical Infrastructure for Public Value Co-creation

4.1. Requirements for Technical Infrastructure

We extrapolate the requirements of the technical infrastructure for public value co-creation based on the model described in the "Theoretical Framework" section (Table 1) and map them to specific components of artefact design. The citizen participation model for the co-creation of public value consists of two parts: government-led and citizen-led approaches. The infrastructures that support government-led participation have been already widely implemented in the form of a dedicated e-participation platform. In this approach, decision-makers present specific topics that the public is interested in and needed for policymaking on a government "owned" citizen online participation platform and then invite citizens to participate in the discussion. In this approach, a government intends to enable citizens to fully utilize allocative resources, in other words, to use online participation platforms without restriction by time and place for the co-creation of public value.

Currently, citizen-led participation is pervasive in the form of voluntary discussion on the issues they are interested in among citizens through social media and citizens' everyday use of private and/or public IoT infrastructure. With the variety of topics and volume of data, it is almost impossible to use them directly for extracting insights for public value creation. Therefore, it is necessary to harness the potential of social media monitoring (henceforth referred to as SMM) and various data processing technologies.

Meanwhile, generally, IoT-based approaches are implemented as an ad hoc process, and processed data is stored for future use. We create the design of our artefact for public value co-creation to extract insights necessary for value creation by tackling the secondary data stored after primary processing.

Implementing the citizen-led approach enables governments to use insights resulting from social media- and IoT-based participation in policymaking and public service provision, and at the same time, citizens' contributions to value creation are officially acknowledged by governments. If the policymakers cannot extract sufficient insights for value creation from social media and IoT-based approaches, they would invite citizens to discuss the topics through the communication channels such as online participation platforms and social media. This process contrasts with the current IoT-based solution in which the initiators focus only on ad hoc processing without including citizens' contributions in policymaking and public service delivery. Governments need to build absorptive capability, including continuously monitoring, processing and storage of data resulting from IoT-based participation, participation framing process, and personalized information service to citizens, to ensure that citizens' contributions are recognized by governments and harnessed constructively. Considering that the goal of designing our artefact is to support technically public value co-creation, it should ensure that a government implements the absorptive capability. The infrastructure has to also support adaptive capability to ensure that citizens are involved in public value creation. This can be provided to citizens in a form of platforms to ensure that citizens can utilize enough adequate allocative resources, including online participation platform, social medial, and IoT, without being restricted in time and place. And, more significantly, the infrastructure needs to support citizens with authoritative resources that ensure their rights directly impact the public value co-creation process. Next, the infrastructure should include innovative capabilities to support ubiquitous participation. Finally, infrastructure has to support risk management capabilities to treat potential risks that decrease citizens' motivation to participate. The artefact has to technically support that a government routinely monitors potential risks related to value co-creation caused by rapidly changing milieus, regularly assesses the priority of risk treatment and treat risks according to it, and inform the treatment results the public.

Table 1. Requirements for technical infrastructure to support the co-creation of public value.

Aspects of citizen-led partiipation		Dynamic capabilities			
		Adaptive	*Absorptive*	*Innovative*	*Risk management*
CleP	*Empower*	R13. Government needs to delivery tools that enable citizens to impact directly the creation of public value	R14. Government needs to establish an approach where citizens' contributions are reflected directly in policymaking.	R15. Government should constantly seek new ways of co-creating public value with citizens	R16. Government should constantly broadcast the results of treating risks, and information related to the potential risks to the public.
	Process	R9. Government needs tools to process data gathered in IoT infrastructure and spontaneous discussions by citizens on social media	R10. Government should analyze IoT and social media data, and recognize valuable citizens' contributions	R11. Government should exploit new technologies for better and faster processing of IoT and social media data	R12. Government should treat the risks, corresponding to the priority of ones.
	Frame	R5. Government needs tools to interact with citizens and frame debates.	R6. Government should analyse citizens' debates and provide frequently the guideline to direct the citizens' debates.	R7. Government should exploit new technologies enabling faster and more relevant interaction with citizens.	R8. Government should regularly inspect the priority of risks treatment, according to changing environment, and redetermine risk priorities.

Aspects of citizen-led partiipation	Dynamic capabilities			
	Adaptive	*Absorptive*	*Innovative*	*Risk management*
Listen & look	R1. Government needs tools to monitor social media data and to gather data resulting from IoT-based citizen participation.	R2. Government needs to acknowledge the citizens' knowledgeability.	R3. Government needs to build ubiquitous IoT infrastructure and construct means that could capture faster and more widely citizens' discussion on multi social media channels.	R4. Government should routinely monitor the potential risks.

The components to implement the requirements of our artefact are derived as follows (Table 2).

Table 2. Technical infrastructure system requirements.

Aspects of citizen-led participation		Dynamic capabilities			
		Adaptive	Absorptive	Innovative	Risk management
CleP	*Empower*	TR13. Policymaking Agenda Setting tool	TR14. Policymaking Agenda Setting tool	TR15. Policymaking Agenda Setting tool	TR16. Risk management tool
	Process	TR9. Multi-source Data Analysis & Management tool	TR10. Multi-source Data Analysis & Management tool	TR11. Multi-source Data Analysis & Management tool	TR12. Risk management tool
	Frame	TR5. Debate Control tool	TR6. Debate Control tool	TR7. Debate Control tool	TR8. Risk management tool
	Listen & look	TR1. Participation Means Monitoring and Exploring tool	TR2. Participation Means Monitoring and Exploring tool	TR3. Participation Means Monitoring and Exploring tool	TR4. Risk management tool

4.2. State of the Art Coverage of the Requirements

In this section, we investigate existing practices and technologies related to the implementation of requirements elicited in the previous section to identify the gaps with respect to the realization of the technical infrastructure for public value co-creation.

We reviewed the literature related to citizen participation for public value co-creation to determine the extent to which the requirements identified in Table 1 are implemented in the existing studies [7, 14-16] and projects such as NOMAD (Policy Formulation and Validation through Non-moderated Crowdsourcing) [1] and Sharing Cities [2]. Our observation discovered that in citizen participation research, there were areas with little or no solutions for citizen-led participation, including aspects of 'Empower', 'Frame', and 'Listen and look'

(Table 2). It is a notice to us that academia and practitioners should pay attention to the study and practice of citizen-led participation for public value co-creation. In particular, existing technologies and methods in terms of the IoT approach tend to focus on ad hoc processing and simple identification of general trends [17], and, a few research discusses the potential of in-depth analysis to extract insights necessary for policy-making and public service provision [8, 18-20]. In addition, unfortunately, we have not discovered research that addresses risk management in the literature related to citizen online participation. Although some literature addresses the issues of risk management and citizen participation [21-25], the study focus of the works is on the topics of citizen participation in risk management rather than on the impact and management of potential risks in citizen participation.

Table 3. Requirements state of the art coverage.

Aspects of citizen-led participation	Dynamic capabilities			
	Adaptive	Absorptive	Innovative	Risk management
Empower	Lack of tools to enable citizens to impact policy-making directly	Lack of an approach where citizens suggestions would be reflected directly in the policy making agenda	Governments are reluctant to seek for new ways of involving citizens into policy making process.	Lack of available, regular process to inform the results of treating risks
Process	Lack of effective tools to facilitate the processing of the vast CleP data, mostly manual processing or simple topic detection & trending	Lack of relevant processes to analyse the CleP data and recognize the valuable contributions, especially, limited recognition of citizen-opinions on social media.	Governments are reluctant to harness new technologies to process more fast contents created by citizen.	Lack of available procedures of risks treatment
Frame	Lack of dedicated, available tools to interact with citizens and frame insights from CleP.	Government do not analyse citizens' discussions on social media and IoT use by citizens is restricted to ad hoc process.	Governments do not try to harness new technologies enabling faster and more relevant interaction with citizens.	Lack of available process to inspect the priority of risks treatment, redetermine risk priorities.
Listen & look	Lack of validated, available tools to monitor social media & IoT based participation data.	No official acknowledgement of citizens' contribution by CleP.	Little support for ubiquitous online participation on various social media tools and IoT infrastructures.	Little support for routinely monitoring the potential risks.

In summary, among the studies mentioned above, the study by Porwol and his co-authors is the most recent study that looked at the state of the art in citizen online participation in relative detail and comprehensively from a unified perspective of government-led and social media-based participation but overlooked the potential risks in citizen online participation and IoT approach that is emerging means of participation in smart cities. Also, Hedestig et al. discussed the potential of integrating IoT with social media to overcome the limitations of the social media approach and conducted a case study on the use of IoT in value co-production. But the authors' research is limited to considering citizen-led participation, such as IoT and social media approaches. Guenduez et al. considered IoT participation in smart cities through two case studies and discussed the potential of IoT participation in public service provision and public policy making. Further, they proposed the concept model of IoT-based participation, consisting of active and passive participation. But their research merely confirmed changes in relations between government and citizens in the process of value creation, and no further work, such as revealing the change mechanism and identifying the governmental capabilities, went on. The limitations mentioned above seem to be since at the time of the authors' research, IoT-based participation was not so mature [7], and their research focus was limited to the use of citizen-led participation tools in public value creation [8, 18].

The dominant citizen participation approach tackled in literature and projects is a government-led approach where decision makers, either directly or indirectly, create new topics of discussion, post them on government-dedicated online participation platforms, and invite citizens to participate in or comment on them. This approach does not guarantee that decision-makers have direct conversations with citizens [7].

4.3. Design of Technical Infrastructure to Support Public Value Co-creation

In previous sections, we elicited the requirements and identified the extent to which the requirements cover based on an investigation of the most recent works related to citizen online participation for public value co-creation to lay the foundation for the design of the technical infrastructure to support the co-creation of public value.

We derive the components necessary for the technical infrastructure to support public value co-creation and create the design (Figure 2). In the infrastructure designed, the adaptive capability is realized by the technical tools for citizen participation, and the tools also serve as the means to implement absorptive and innovative capabilities. Risk management capability is realized by the risk management toolkit. The names of the components were simplified for the clarity. The technical infrastructure consists of Information Processing Area, including Decision-Maker Interface Toolkit, Data Analysis and Management unit, and Risk Management unit, and Information Mining and Publishing Area to support that government leads the direction of citizens' discussions as experts and publishes various information.
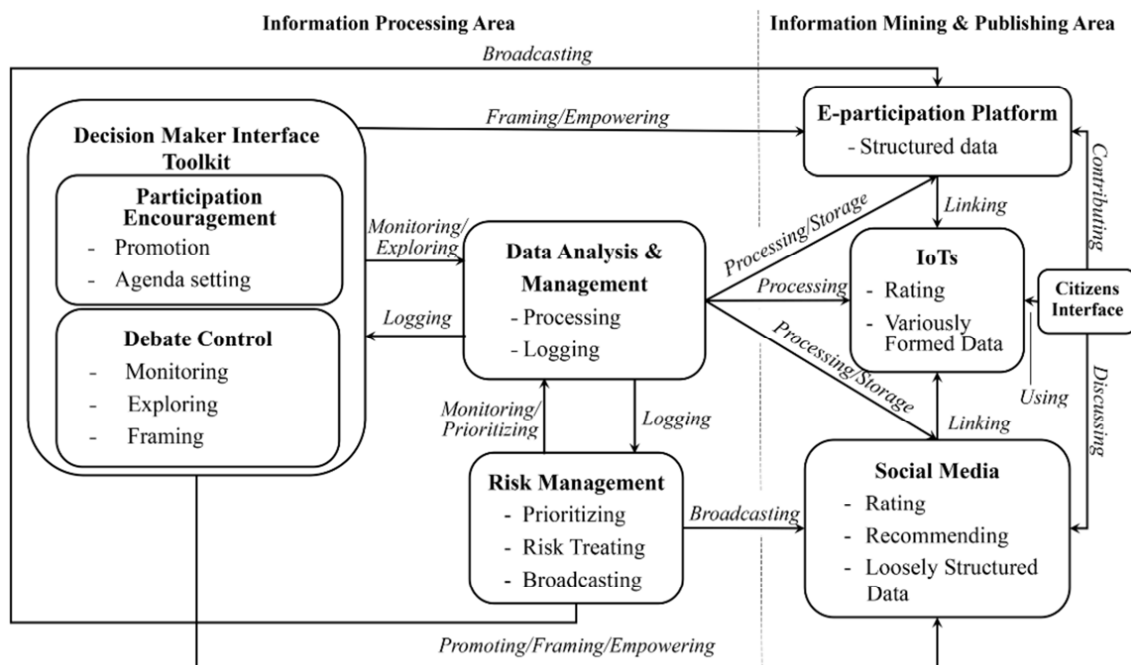

Figure 2. Technical infrastructure to support the co-creation of public value.

We organized the infrastructure units according to tasks performed in the co-creation process. Decision Maker Interface toolkit involves Participation Encouragement tool and Debate Control tool. Here, the Participation Encouragement tool has gathered the functions to promote citizen participation and enable citizens to impact direct policy agendas as a part of

authoritative resources. The Debate Control tool conducts the functions to monitor and explore continuously processes in Data Analysis & Management unit. A government uses the Debate Control tool to engage in voluntary citizens' discussions on social media, directing their discussions and recommending to participants if necessary. In addition, the Debate Control tool also conducts functions that post topics on online participation platforms and/or social media to invite citizens to participate in the related discussion if a decision maker has not found sufficient insights for value creation from analysis of IoT data and voluntary citizens' debates.

The Risk Management tool conducts functions that regularly specify the order of risk treatment according to the changing milieus; continuously monitor Data Analysis & Management unit; assist decision-makers with treating them based on the priority once occur risks; and inform citizens of the results through communication channels.

One of the important functions of the Data Analysis & Management tool, which is core unit in the technical infrastructure, is to search and analyze data produced from participation platforms, social media, and IoT. In addition, this component determines priority of insights related to policy agenda extracted from social media and IoT and records their metadata to connect with the original contributions. Another function of this component is to create and maintain logs of other tools, such as Participation Encouragement, Debate Control, and Risk Management, provide feedback on them, and analyze log content. Eventually, decision-makers should be able to use the designed artefact to harness citizens' contributions to the public value creation process.

To ensure the correctness and validity of the designed artefact, we need to confirm that the design is valid for the requirements in Tables 1 and 2. Considering the components of our artefact were directly mapped based on a detailed analysis of the requirements, it can be argued that the artefact will satisfy the requirements. We align the designed building blocks to the determined requirements of technical infrastructure to support public value co-creation.

Table 4. *Alignment of the requirements to the related design components.*

Aspects of citizen-led participation		Dynamic capabilities			
		Adaptive	Absorptive	Innovative	Risk management
CleP	Empower	R13- Participation Encouragement, Agenda Setting	R14-Participation Encouragement, Agenda Setting and Promotion	R15-Dada Analysis & Management, Logging	R16-Risk Management, Broadcasting
	Process	R9- Data Analysis & Management, Processing	R10- Data Analysis & Management, Processing; Debate Control, Exploring	R11- Data Analysis & Management, Logging	R12- Risk Management, Treating
	Frame	R5- Debate Control, Shaping	R6- Debate Control, Shaping; Participation Encouragement, Promotion	R7- Data Analysis & Management, Logging	R8- Risk Management, Prioritizing
	Listen & look	R1- Debate Control, Monitoring	R2- Debate Control, Monitoring and Exploring	R3- Data Analysis & Management, Logging	R4- Risk Management, Monitoring

The proposed artefact enables it to harness the synergy between government-led and citizen-led participation, including social media and IoT-based participation.

In the following section, we discuss the implementation possibility of the artefact.

4.4. Implementation of Technical Infrastructure

The Participation Encouragement and Debate Control unit can be implemented directly through dedicated online participation platforms and governmental social media pages. The functions of this unit can be significantly improved by applying targeted participation advertising such as Facebook Targeted Additions[3] or Promoted Twitter[4]. RDF-based Linked Data[5] technologies could be harnessed for metadata and information inference with detailed information on the original contributions. The Risk Management unit could be realized by using dedicated risk management tools such as nTask[6], Resolver[7], TimeCamp[8], and Integrum[9]. Especially, nTask is considered one of the sound risk management tools due to its characteristics, including Professional Risk Reporting, Easy Visibility, Demine Risk Impact, Risk Matrix, Custom Fields, and Risk Assessment Graph. Data Analysis & Management unit could be realized by automatic or semi-automatic content analysis tools such as Open Text Summarizer (OTS)[10] and MEAD[11], or natural language processing tools such as NLTK[12] and Stanford Core NLP[13]. Harnessing citizen-led participation for value co-creation needs the tools (Debate Control and Data Analysis & Management) to analyze social media and IoT data; Bottlenose[14], SproutSocial[15], UberVU[16], Visible[17], NetBase[18], and NUVI[19] could be used to analyze social media data, while analysis of IoT data could be conducted by IoT data analysis and visualization tools such as AWS IoT Analysis[20], SAP Analysis Cloud[21], and IBM Watson IoT Platform[22]. AWS IoT Analysis is a completely managed service that automates the most difficult tasks related to IoT data and makes it easy to execute complex data analysis algorithms. SAP Analysis Cloud has the option of integrating IoT data into analysis solutions and better analyzing and visualizing data. SAP Analysis Cloud and IBM Watson IoT Platform provide natural language processing, machine learning, image and text analysis, which enrich IoT apps. Linked Data technology could be used to structure discussions in multi-platforms and integrate them into a single knowledge base. This technology further enables decision-makers to contact the original contributors. For Monitoring capability implementation, dedicated ontology such as SIOC Ontology[23], which is enhanced with an Argument Extension that combines content summary tools such as OTS, can be applied.

5. Validity of Technical Infrastructure: Comparative Analysis

Considering the fact that citizen participation is a prerequisite for public value co-creation [26, 27] and the relationship between citizen participation and co-creation [26-29], it is believed that there is no difference in nature between the technical infrastructure for public value co-creation and online participation infrastructure. The infrastructure supporting government-led participation in public value co-creation has been extensively introduced in the form of "government-owned" platforms [30]. However, ideal citizen participation platforms should find a way to incorporate citizen-led approaches into the online-participation process [31]. Some systems can integrate inputs from citizen-led participation such as the social media approach, and tend to receive researchers' preference [32], but these are not adopted widely in practice [31]. Under this background, in 2018, Porwol and his co-authors developed the Social Software Infrastructure (*Henceforth referred to as SSI*) to integrate social media-based participation into government-led participation [7]. SSI is one of the most widely cited technical constructions [6, 31, 33], and it also considers comprehensively the socio-technical aspects of citizen online participation [33]. In this work, therefore, we adopt comparative analysis with SSI in examining the validity of technical infrastructure for public value co-creation. For this purpose, it is necessary to identify the factors for the comparative analysis between the two artefacts. In the following subsection, we explore the factors for comparative analysis.

5.1. Factors for Comparative Analysis

For comparative analysis, we set up five parameters, including Public Value Co-creation Scope Perspective, Participant Perspective, Data & Information Perspective, ICT Tool Perspective, and Governance Perspective based on the work by Scherer and Wimmer that analyse the citizen online participation models and employ the enterprise architecture frameworks in integrating the different concepts forming an online participation project [34].

The purpose of the Public Value Co-creation Scope Perspective is to capture the insights related to the issues of interest by stakeholders of public value creation, determine the objectives of the project and link them with measures to achieve them. It makes us evaluate whether the artifacts provide information necessary for the initiators to decide whether they will initiate the project or not and the basis for further progress after a positive decision.

The purpose of the Participant Perspective is to identify and manage the participants, who are actively and passively engaged in the project or benefit from the public value created. It makes us evaluate whether the artifacts provide information needed to allocate roles to participants.

The Data & Information Perspective describes the data that is produced or consumed within public value co-creation.

This perspective aims to evaluate how the related information is managed within the technical infrastructure.

The ICT Tool Perspective is related to evaluating the technical representation of the applications required to implement the participation architecture, its deployment, and operation. It, therefore, describes the general architecture of the applications: their structure, distributions and how they are interconnected, and a technical description of the applications.

The Governance Perspective considers the operational management of the public value co-creation project and governance of architecture implementation. It makes us evaluate whether the artefacts address the concern of determining the constraints in the citizen online participation process and assessing the outcomes. The perspective is also related to employ risk management.

5.2. Social Software Infrastructure of E-participation vs. Technical Infrastructure for Public Value Co-creation

Porwol and his co-authors developed SSI for e-participation enabling decision-makers to harness government-led and social media-based participation (Figure 5-1) [7]. The authors divided the design space into two parts: Information Processing Space and Information Mining & Publishing Space. The Black and White components represent the tool containers, while the arrows represent the interfaces. The Citizen Interface is given a distinguished representation as it represents a set of both mobile- and web-mediated access to social media and dedicated e-participation platforms. SSI has been grouped the Policy-making Agenda Creation Tool under Mission Control Tool since the function of the components is complementary to the Promotion of active citizen engagement reinforced by recognition of citizens' contributions. Similarly, the Discussion Exploration and Analytics tools have been grouped as part of the Discussion Control (DC), as the tools deliver a subset of the essential functions of the DC. According to the authors, a central component of SSI is the Data Analytics Component they refer to as Knowledge Extraction & Management (KEM). This component is primarily responsible for all e-participation related data and metadata processing within SSI. The input data can be fetched from social media and dedicated e-participation platforms via available APIs to produce structured information. Depending on the source and input data structure, additional metadata can be retrieved for the analysis such as Ratings and Recommendation Links. The same APIs are used by the KEM to publish data on social media-based and government-led platforms. Therefore, KEM provides the output gate for information gathered, processed, and published. In principle, the KEM component analyses the data, i e., posts, user profiles, discussion topics, and threads, and performs continuous data quality improvement by filtering and linking related concepts as well as data from external sources such as other e-participation systems, governmental portals or any other places holding valuable e-participation information.
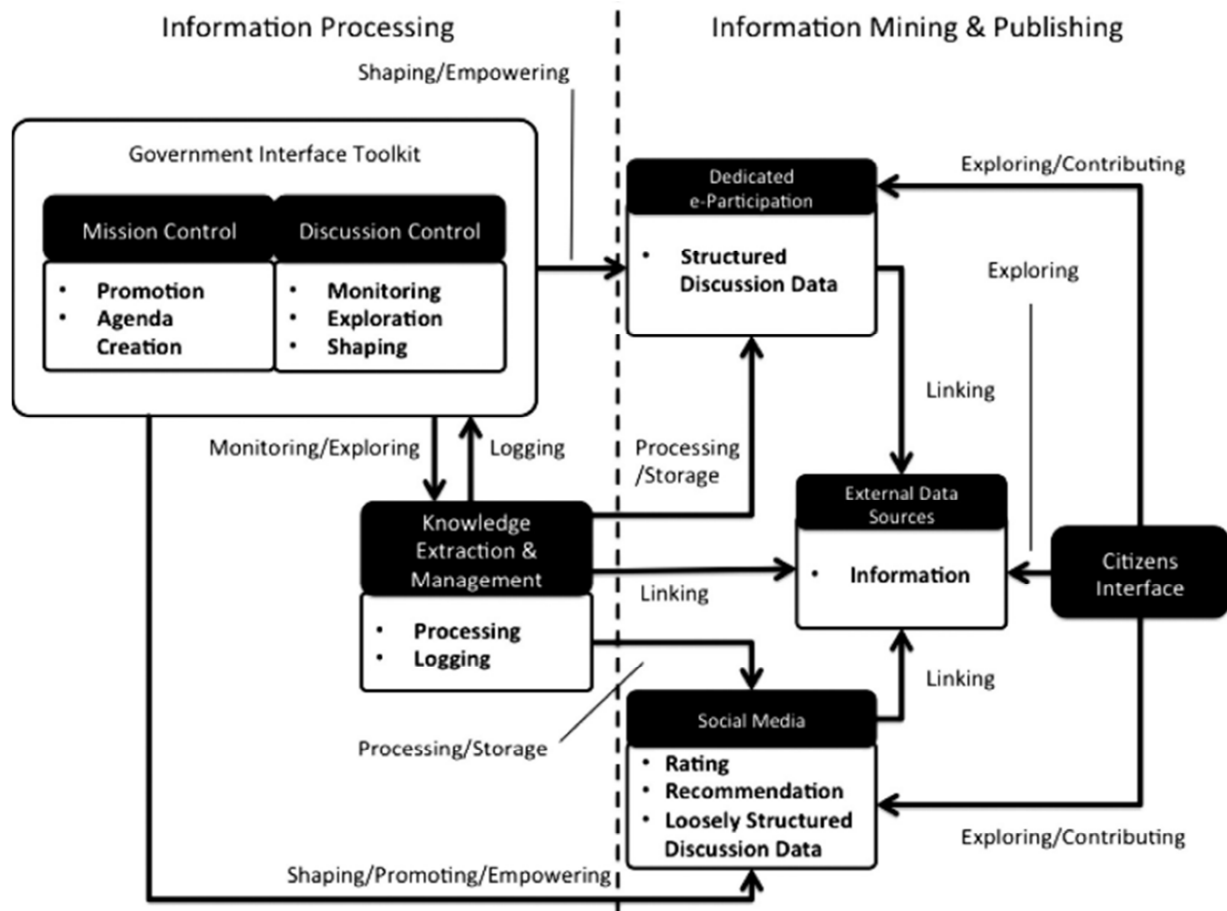
Figure 3. Social software infrastructure for e-participation [7].

The secondary function of the component is to create and maintain logs and service feedback for all the other infrastructure components and perform analysis on the log contents. This way, the Knowledge Extraction & Management component enables a better understanding of the processes and future system re-shaping and reproduction through the application of relevant improvements. Unlike the social media platforms, the dedicated e-participation platforms hold more structured data in a form of hierarchical forum data or argumentation tree data. The information is mined and processed by the Information Processing Component (IPC) encapsulating all the tools responsible for Discussion & Mission Control and KEM - the Information Processing part of SSI design.

Decision-makers explore the content through IPC and stimulate the participation by frequent feedback to active contributors and by shaping deliberations through contributions in selected discussions.

Table 5 shows the comparative analysis of two artefacts in terms of the five perspectives mentioned in the previous section.

In SSI for e-participation, information sources for insights extraction for policy making and public service provision include the government-owned official platform and social media, while our artefact not only includes the official tools

and social media but also is extended to IoT, information necessary for the initiators to decide whether they will initiate the project or not and the basis for further progress after a positive decision are more comprehensive relatively. The central components of the two artefacts are Knowledge Extraction & Management and Data Analysis & Management respectively, which are primarily responsible for all online participation-related data and metadata processing within the infrastructures. In the Knowledge Extraction & Management component of SSI for e-participation, input data is fetched from social media and dedicated e-participation platform via available APIs to produce structured information, while input data within our artefact is complemented by IoT. Considering the benefits of IoT-based participation mentioned in the previous part, the complementation of IoT data make decision-makers possible to decide more comprehensive and representative decision.

Integrating IoT-based participation into public value co-creation increases vastly the scope of participants since it makes social groups, such as minors, temporary residents, and the disabled, who are unable to engage in the public value co-creation process possible engage. This way, with the increased representativeness of the extracted insights, it leads to improving democracy in city governance and ensuring the implementation of public policy and public service provision

as it reaches the consensus of wider social groups.

Table 5. Social software infrastructure vs. Technical infrastructure for public value co-creation.

| | Perspective | | | | |
	Public value co-creation Scope	Participant	Data & Information	ICT tool	Governance
SSI for e-participation	Less comprehensive	Less diverse	Input data: structured data, loosely structured data, metadata, logs Output data: structure data	RDF-based Linked Data, Open Text Summarizer (OTS), NLTK, SocialMention, Bottlenose, Apache Jena TDB	Not consider potential risks
Our artefact	More comprehensive	More diverse	Input data: structured data, loosely structured data, variously formed data, metadata, logs Output data: structured data	RDF-based Linked Data, nTask, Open Text Summarizer (OTS), NLTK, Bottlenose, AWS IoT Analysis, SIOC Ontology	Consider potential risks

In terms of data format, in SSI for e-participation, input data is the structured, semi-structured, and loosely structured data, while input data in our artefact is added by variously formed data such as digit, audio, image, and video data and output data are the structured data. It is needed to consider ICT tools supporting a more comprehensive data format in realizing the technical infrastructure for public value co-creation.

For the implementation of the infrastructure, Porwol et al. plan to harness the ICT tools such as RDF-based Linked Data, which could be used for more descriptive metadata and effective information inference with detailed information about the origin and authorship of the contributions, Open Text Summarizer (OTS) - automatic or semi-automatic content summarization tool, NLTK - the natural language processing tool, and Bottlenose - the social media analysis tools. We plan to employ in addition the ICT tools such as AWS IoT Analysis - the IoT data processing tool and nTask -the risk management tool.

In SSI for e-participation, potential risks within the citizen online participation lifecycle are not tackled, while our artefact addresses potential risks in the Risk Management unit. Considering that citizen online participation is conducted in the dynamic and complex social milieus, risk management is a critical component for successful public value co-creation initiatives.

6. Discussion

In Table 5, regarding the Public value co-creation Scope and Participant perspective, the source of information utilized for the insight extraction necessary for public value co-creation in our artefact is more comprehensive than SSI by Porwol [7] as IoT has been integrated, which guarantees more comprehensive citizen participation in the process of public value co-creation. In the process of public value co-creation, integrating IoT opens up the opportunity to overcome the limitations inherent in the social media approach, and, especially, has great possibilities for addressing social issues, such as the digital divide and engagement inequality, and can include the disabled, minors, and temporal residents, who were previously unable to participate in the process of creating public value. It means that our artefact could support normal citizens as well as special citizen groups, such as minors, temporal residents,

and the disabled, to exercise their agency in urban governance, in turn leading to the improvement of democracy in urban governance. IoT also leads to positive changes in the way citizens live and in the order of behavior. For example, cameras installed along roads in cities enable the public service organizations to gather data related to road use by residents to utilize for public service, and, at the same time, the cameras stimulate citizens' awareness of compliance with traffic regulations, leading to changes in road user behavior. Thus, the data collected from the infrastructure with embedding IoTs are behavioral data reflecting citizens' consciousness caused by the introduction of IoT. To summarize, we believe that our artefact is a social technology that enables it to make considerable progress in improving democracy, improving the quality of citizens' life, and securing the sustainable development of cities.

In Table 5, as shown by the comparison of Data & Information, and ICT tools perspective, the integration of IoT-based participation makes the data formats addressed in the technical infrastructure for public value co-creation more diverse than SSI. The diverseness of data formats requires addressing technical challenges concerning implementing the technical infrastructure and harnessing ICT tools, which is one of the crucial challenges that would be addressed in developing the technical infrastructure.

Finally, the Risk Management unit in our artefact can effectively deal with the potential risks that may arise in the process of public value co-creation, which ensures the success of the initiative of public value co-creation. Citizen online participation is conducted in an open environment, so it cannot be argued that the possibility that various potential risks hindering citizen participation will arise is not high. For example, cyberattacks, invasion of privacy, and misuse of sensitive personal data can significantly reduce citizens' motivation to participate and lead to increased distrust in the government. Therefore, properly dealing with these potential risks is not a purely technical challenge, but is a social issue related to citizens' trust in the government and social stability. Only by dealing with these social issues can enhance the quality of citizens' life, ensure the sustainable development of cities, improve democracy in city governance, and create value "for citizen, by citizen." Given the importance of risk management in public value co-creation, we believe that our artefact can become a better alternative for policymakers and decision-makers.

7. Conclusion

In this paper, we have designed a technical infrastructure to support the co-creation of public value, based on the citizen participation model for public value co-creation that re-conceptualized citizen online participation expanded by citizen-led participation from the perspective of structures and agents. For this purpose, first, we have elicited the requirements of technical infrastructure necessary to harness citizen-led participation from the citizen participation model for public value co-creation and identified the components of infrastructure. Second, we have investigated the existing practices and technologies to look at the extent to which the elicited requirements are covered so that it identifies the gaps related to the requirements. Third, we have created the design of technological infrastructure to harness the synergy between government- and citizen-led participation, including social media and IoT-based participation. Forth, its implementation scenario by existing technologies was discussed. Finally, we examined the validity of the technical infrastructure for public value co-creation through the comparative analysis with SSI for e-participation by Porwol, which is cited widely in literature and addresses comprehensively the socio-technical aspects of citizen online participation. For comparative analysis, we have set up six parameters, including Public Value Co-creation Scope Perspective, Participant Perspective, Data & Information Perspective, ICT Tool Perspective, and Governance Perspective based on the work by Scherer and Wimmer that analyze the citizen online participation models and employ the enterprise architecture frameworks in integrating the different concepts forming an online participation project. The results of the comparative analysis show that our artifact has the possibility of ensuring to archive considerable progress in improving democracy in urban governance. While it also raises the technical challenges that would address in the process of implementing the technical infrastructure.

Harnessing the proposed technical infrastructure could improve the role of citizens in public value creation and further empower citizens in urban governance. To date, there are several studies to harness IoT in the public sector setting, but they are mainly limited to ad hoc processing, and there are little attempts to analyze them to predict citizens' demands and utilize them for policymaking. Moreover, few attempts have been made to combine social media and IoT as an alternative to overcome the practical limitations of the social media approach in public value co-creation.

In addition, existing solutions are considered simple social media-based or IoT-based solutions without an in-depth consideration of the unique attributes of citizen participation and the theoretical basis. The model that we employ as the theoretical basis for the design of our artefact is based on Giddens' structuration theory, which is one of the most powerful and most widely adopted social theories in interpreting change in the social system due to the introduction of ICT, and dynamic capability theory, which

is a remarkable theoretical framework in the management community. In this sense, it could be argued that the proposed technical infrastructure is more general and comprehensive than other solutions. We have designed our artefact based on the fact that IoT is one of the key technology tools used in smart cities and is a very flexible digital means for information exchange with other ICT tools. The designed technical infrastructure could be seen as a good alternative for public agencies suffering to create value cooperatively with citizens.

We do not claim the absolute validity of our artefact despite our struggle with examining the validity of the technical infrastructure for public value co-creation proposed in our paper. Furthermore, we do not deny the possibility that unanticipated social-technical challenges will arise in the process of realizing infrastructure. In particular, technical challenges can only be identified by operating the artefact in practice. But our work is valuable in that it is the first attempt that addresses the possibility of harnessing the synergy between government- and citizen-led participation, including social media and IoT-based participation that is becoming a ubiquitous phenomenon in practice.

References

[1]   A. M. Townsend, Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia: W. W. Norton & Company, 2014.

[2]   M. P. Rodríguez Bolívar, "Public Value, Governance Models and Co-Creation in Smart Cities," Setting Foundations for the Creation of Public Value in Smart Cities, Public Administration and Information Technology, pp. 271-280, 2019.

[3]   E. Cosgrave, and T. Tryfonas, "Exploring the relationship between Smart City policy and implementation," in SMART 2012: The First International Conference on Smart Systems, Devices and Technologies Stuttgart, Germany, 2012, pp. 79-82.

[4]   A. Macintosh, S. Coleman, and A. Schneeberger, "eParticipation: The Research Gaps ". pp. 1-11.

[5]   H. J. Cao, and C. I. Kang, "A citizen participation model for co-creation of public value in smart city," Journal of Urban Affairs, 2022.

[6]   A. Simonofski, J. Fink, and C. Burnay, "Supporting policy-making with social media and e-participation platforms data: A policy analytics framework," Government Information Quarterly, vol. 38, no. 3, 2021.

[7]   L. Porwol, A. Ojo, and J. G. Breslin, "Social Software Infrastructure for e-Participation," Government Information Quarterly, vol. 35, no. 4, pp. S88-S98, 2018.

[8]   U. Hedestig, D. Skog, and M. Söderström, "Co-producing public value through IoT and social media."

[9]   S. T. March, and G. F. Smith, "Design and natural science research on information technology," Decision Support Systems, vol. 15, pp. 251-266, 1995.

[10] A. Giddens, The constitution of society: University of California Press, 1984.

[11] C. L. Wang, and P. K. Ahmed, "Dynamic capabilities: A review and research agenda," International Journal of Management Reviews, vol. 9, no. 1, pp. 31-51, 2007.

[12] Y. Bogodistov, and V. Wohlgemuth, "Enterprise risk management: a capability-based perspective," The Journal of Risk Finance, vol. 18, no. 3, pp. 234-251, 2017.

[13] A. Roberts, "Bridging Levels of Public Administration: How Macro Shapes Meso and Micro," Administration & Society, vol. 52, no. 4, pp. 631-656, 2019.

[14] Ø. Sæbø, L. S. Flak, and M. K. Sein, "Understanding the dynamics in eParticipation initiatives: Looking through the genre and stakeholder lenses," Government Information Quarterly, vol. 28, no. 3, pp. 416-425, 2011.

[15] Y. Charalabidis, A. Triantafillou, V. Karkaletsis et al., "Public Policy Formulation through Non Moderated Crowdsourcing in Social Media," Electronic participation. ePart 2012, Lecture notes in computer science E. Tambouris, A. Macintosh and Ø. Sæbø, eds., pp. 156–169: Springer, 2012.

[16] I. Susha, and Å. Grönlund, "eParticipation research: Systematizing the field" Government Information Quarterly, vol. 29, no. 3, pp. 373–382, 2012.

[17] F. Salim, and U. Haque, "Urban computing in the wild: A survey on large scale participation and citizen engagement with ubiquitous computing, cyber physical systems, and Internet of Things," International Journal of Human-Computer Studies, vol. 81, pp. 31–48, 2015.

[18] A. A. Guenduez, T. Mettler, and K. Schedler, "Citizen Participation in Smart Government: A Conceptual Model and Two IoT Case Studies," Beyond Smart and Connected Governments, Public Administration and Information Technology, pp. 189-209, 2020.

[19] J. R. Gil-Garcia, T. A. Pardo, and M. Gasco-Hernandez, "Internet of Things and the Public Sector," Beyond Smart and Connected Governments, Public Administration and Information Technology, pp. 3-24, 2020.

[20] C. Liu, M. Balestrini, and G. N. Vilaza, "From Social to Civic: Public Engagement with IoT in Places and Communities," Social Internet of Things, Internet of Things, pp. 185-210, 2019.

[21] P. S. Hart, E. C. Nisbet, and J. E. Shanahan, "Environmental Values and the Social Amplification of Risk: An Examination of How Environmental Values and Media Use Influence Predispositions for Public Engagement in Wildlife Management Decision Making," Society and Natural Resources, vol. 24, no. 3, pp. 276-291, 2011.

[22] S. A. Forrest, E.-M. Trell, and J. Woltjer, "Emerging citizen contributions, roles and interactions with public authorities in Dutch pluvial flood risk management," International Journal of Water Resources Development, vol. 37, no. 1, pp. 1-23, 2021.

[23] Z. Nkombi, and G. J. Wentink, "The role of public participation in disaster risk reduction initiatives: The case of Katlehong township," Journal of Disaster Risk Studies, vol. 4, pp. 1, 2022.

[24] S. Samaddar, N. Okada, J. Choi et al., "What constitutes successful participatory disaster risk management? Insights from post-earthquake reconstruction work in rural Gujarat, India" Nat Hazards, vol. 85, pp. 111-138, 2017.

[25] U. Wehn, M. Rusca, J. Evers et al., "Participation in flood risk management and the potential of citizen observatories: A governance analysis," Environmental science & policy, vol. 48, pp. 225-236, 2015.

[26] O. Grcheva, and B. Oktay Vehbi, "From Public Participation to Co-Creation in the Cultural Heritage Management Decision-Making Process," Sustainability, vol. 13, no. 16, 2021.

[27] J. Pappers, I. Keserü, and C. Macharis, "Co-creation or Public Participation 2.0? An Assessment of Co-creation in Transport and Mobility Research," Towards User-Centric Transport in Europe 2, Lecture Notes in Mobility, pp. 3-15, 2020.

[28] K. Prager. "Is co-creation more than participation?," https://i2insights.org/2016/07/28/co-creation-or-participation/.

[29] I. Bizjak, "Web 2.0 tools as framework for participation and co-creation," Co-Creation of Public Open Places. Practice - Reflection - Learning, Culture and Territory, pp. 227-241, 2020.

[30] UN, E-Government survey 2020: Digital government in the decade of action for sustainable development, United Nations, 2020.

[31] A. Simonofski, E. Hertoghe, M. Steegmans et al., "Engaging citizens in the smart city through participation platforms: A framework for public servants and developers," Computers in Human Behavior, vol. 124, 2021.

[32] J. Dolson, and R. Young, "Explaining variation in the e-Government features of municipal websites: An analysis of e-Content, e-Participation, and social media features in Canadian municipal websites," Canadian Journal of Urban Research, vol. 21, pp. 1-24, 2012.

[33] T. R. Coelho, M. Pozzebon, and M. A. Cunha, "Citizens influencing public policy-making: Resourcing as source of relational power in e-participation platforms," Information Systems Journal, vol. 32, no. 2, pp. 344-376, 2021.

[34] S. Scherer, and M. A. Wimmer, "E-participation and enterprise architecture frameworks: an analysis," Information Polity, vol. 17, no. 2, pp. 147–161, 2012.

1 https://cordis.europa.eu/project/id/288513
2 https://sharingcities.eu/
3 https://www.facebook.com/about/ads/
4 https://business.twitter.com/products/promoted-tweets-selfservice
5 http://www.w3.org/standards/semanticweb/data
6 https://www.ntaskmanager.com/blog/best-risk-management-software/
7 https://www.resolver.com/
8 https://www.timecamp.com/applications/
9 https://www.integrumws.com/
10 http://libots.sourceforge.net/
11 http://www.summarization.com/mead/
12 http://nltk.org/
13 http://nlp.stanford.edu/software/corenlp.shtml
14 http://bottlenose.com/
15 http://sproutsocial.com/
16 http://www.ubervu.com/
17 http://www.visibletechnologies.com/
18 http://www.netbase.com/
19 http://www.nuviapp.com/
20 https://aws.amazon.com/iot-analytics/?nc=sn&loc=0
21 https://www.sap.com/products/cloud-analytics.html
22 https://internetofthings.ibmcloud.com/
23 http://www.w3.org/Submission/sioc-spec/