Depicting the Smarter Cities of the Future: A Systematic Literature Review & Field Study

T. Raaijen and M. Daneva

Abstract— **Smart Cities have become one of the most interesting research topics for governments, businesses and researchers in the last few years. Being a Smart City implies a competitive edge compared to other cities in terms of economic growth, sustainability, human resources and governance. Therefore, more and more governments pursue this future vision and hop onto the Smart City `Bandwagon'. However, the development of Smart City solutions is faced with challenges since there is no clear definition for Smart Cities yet. This paper provides a review on what challenges arise when designing Smart City solutions to provide a complete overview of identified challenges. This paper carries out a systematic literature review of publications between 2008 and 2016 which will be compared with a field study on Smart City initiatives conducted by the municipality of Enschede to develop a requirements framework for these projects. This research is relevant to governments and businesses aiming to create Smart Cities and for researchers, who aim to enhance the concept of Smart Cities. This paper found eight sub-domains within the topic of Smart Cities and these are: Technical Infrastructure, Application Domains, System Integration, Data Processing, Governance & Management, Society & Citizens, Business Domain and Environmental Sustainability. The eight sub-domains are respectively divided in two types: technological and non-technological domains. By firstly identifying the challenges and their solutions within these sub-domains, this paper proposes a requirements framework in combination with a check-list of questions to provide guidance for promoters to conduct future initiatives.**

Index Terms **— Challenges, Qualitative Interview, Requirements Framework, Smart Cities, Systematic Literature Review**

I. Introduction

In the past decade, the notion of developing Smart Cities has accumulated more interest of stakeholders from different backgrounds, among them are academia and businesses [29]. As discussed by Kitchen [33], information systems play a vital role in the development of infrastructure enhancing technologies. The 'Internet of Things' and other ICT advancements provide an extensive backlog for opportunities to introduce new IT applications into the fabric of the city's infrastructure [68]. Governments and businesses around the globe have already jumped on the developing of Smart Cities `Bandwagon' by introducing information systems into the fabric of their cities [34, 44]. These applications serve to enhance the city's economy, mobility, environment, human resources, quality of living and governance [27, 68, 70]. The key pillar to achieve these city advancements is the access to reliable data [1], to improve city-wide efficiency by i) monitoring, ii) managing and iii) regulating the city's infrastructure [33]. Other governments and businesses have built Smart Cities even from scratch [10, 23]. However, the question still remains whether these `greenfield' cities are the smartest alternative for governments and businesses to focus on [53].

This paper contributes to the topic of Smart Cities by developing a requirements framework which helps policymakers and governments to determine whether their envisioned Smart City initiatives are viable and enhancing the city's infrastructure. This paper also contributes to the definition of Smart Cities. Governments, businesses and academia can identify challenges of developing Smart City solutions when considering their own demands of Smart Cities by reading this paper. For this purpose, challenges encountered during the development of Smart City solutions and are identified in published work between the years of 2008 and 2016 are framed in this paper.

A. Problem statement

The development of Smart Cities has become one of the hottest research topics of this century [29]. Nonetheless, a detailed description of the Smart City concept is still absent as identified by Kitchen [33] and Neirotti, et al. [45], which endangers this vision. For this research, the remainder of this paper adopts Townsend's definition of Smart Cities: “places where information technology is combined with infrastructure, architecture, everyday objects, and even our own bodies to address social, economic and environmental problems” [62]. Moreover, the variety of stakeholders do have different goals [23], which endanger the view on Smart Cities. Because of the absence of a clear definition and the different stakes, Glasmeier and Christopherson question the viability of Smart City solutions [21]. This paper answers what challenges endanger the applicability of IT in the Smart City context.

B. Research questions

This research will provide an answer to the following research questions (RQs):

RQ 1: What challenges does the development of information systems for Smart City applications face according to recent publications (2008-2016)?

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RQ 2: How do current Smart City initiatives translate into a requirements framework, according to the field study in the municipality of Enschede and the case studies found in the literature?

RQ 3: What solutions have been proposed to counter the challenges for Smart City Initiatives, according to published literature? And which of these challenges are still under-researched?

C. Paper structure

This paper is structured as follows: Section II presents background and Section III - related work. Section IV describes the research methodology. Section V reports on the challenges of Smart Cities as per the reviewed literature. Section VI proposes a requirements framework. Section VII discusses the findings and Section VIII concludes this research.

II. Background

This research sheds a light on the ongoing challenges of Smart City initiatives. To that extent, the necessity exists of understanding the current state in which the research on Smart Cities is. The field of Smart Cities is still in its infancy, meaning that there still is much research to be done on how to create the smarter cities of the future. In the literature on smart cities, there are attempts to clarify the meaning of this term and to provide a characterization of smart city initiatives [45, 70]. The authors of these papers concluded that there is still no sound definition of Smart Cities and how to tackle their associated adversities. This work rests on their analysis and aims to provide guidelines for Smart City initiatives by identifying commonly encountered challenges.

III. Related work

This systematic literature review is based on a variety of literature reviews and surveys on Smart cities [68], information systems for Smart Cities [36] and a mobility survey in the context of enhancing the city's infrastructure [46]. These publications provide a wide spectrum of Smart City advancements that are aimed to pinpoint the vital role of IT in the fabric of the city's infrastructure, while other studies aim to develop Smart City frameworks [4, 38]. Moreover, this research is based on Smart City initiatives conducted by the municipality of Enschede aiming to enhance the infrastructure of the city. Various local projects are, for example, the "Living Smart Campus" project and the SMART mobility application [19, 64]. Furthermore, in the past few years' initiatives have provided a backlog of case studies on creating intelligent cities around the globe [2, 11, 18, 23, 29, 34, 35, 41, 44, 48, 57, 66]. The case studies have discussed ways to create Smart Cities and identified challenges for successfully integrating systems.

IV. Research Methodology

The research questions (RQs) will be answered by conducting a systematic literature review following the methodology described by Kitchenham [32]. Then, a field study on current endeavours by the municipality of Enschede will be conducted to develop a requirements framework. It was chosen to conduct a systematic literature study in combination with the field study, because of the intention to provide a complete overview of heretofore conducted research on Smart Cities and to provide a guideline for policy-makers to assess the viability of Smart City initiatives.

A. Data retrieval

In the search for relevant publications, the Scopus database is consulted. This included peer-reviewed papers in conferences and journals. Master's theses and dissertations were not included in this research.

1) Filtering results in Scopus

The search string ((“smart cities” OR “smarter cities” OR “cities of the future”) AND (challenges OR issues OR problems) AND (“information system” OR ict)) has been used to find relevant papers. This search query was carried out to search in Article Title, Abstract and Keywords. By applying limitation criteria, the data range was limited to solely find papers between 2008 and April 2016. The year of 2008, as limited in RQ 1, is chosen, because it marks the introduction of the smart city concept in multiple research programs at a global level after one of its first appearances in the year 1997 [54]. With the search string and the limitation criteria described above, the Scopus database provided 153 results.

2) Filtering results based on their relevance

After this first stage of limiting papers, the second stage was to exclude prefaces and reading the titles and abstracts from the remaining interesting papers. This resulted in 29 interesting publications. The last stage will be reading the full texts of these 29 publications.

B. Developing the requirements framework

The field study conducted within the municipality of Enschede investigates what Smart City initiatives are undertaken currently by means of qualitative interviewing based on the so-called Coding technique [55]. Moreover, this study aims to identify existing challenges for these projects to become successful. The purpose of identifying these challenges is to develop a requirements framework which can help promoters to determine if projects will provide the envisioned outcomes in terms of enhancing the city's infrastructure. This framework will identify the influential requirements as characteristics for the success of the envisioned project. The extensive backlog of Smart City initiatives, as indicated in Section III, provides an academic background to the findings of this field study. This case study is chosen due to two reasons: i) The associated municipality of this case study was close by, simplifying the communication with its representative and ii) the representative of the municipality was willing to invest time in helping this research to progress.

C. Purposes of this study

The research questions will be answered as following: all challenges for the development of Smart Cities identified in the publications are extracted to answer RQ 1. Then, the findings of the field study in this research are compared to the findings of RQ 1. To that extent, the implications of these findings on the outcome provide a well-established ground to develop a requirements framework for future initiatives (RQ 2). Finally, proposed countermeasures identified in the literature are provided at the end of this research to point out future work in the field of creating Smart Cities (RQ 3).

V. SMART CITY CHALLENGES

The 29 selected papers will now be classified based on the taxonomy identified by Yin et al. [68]. This classification enforces the identification of encountered challenges and their solutions, serves to answer RQ1 and RQ3 as well as providing guidance for future directions, because it serves to identify areas that are less researched than other subjects on a per sub-domain basis (RQ3). Yin et al. provides a taxonomy referring to four domains of either technical challenges and non-technical challenges [68], as depicted in Figure 1.

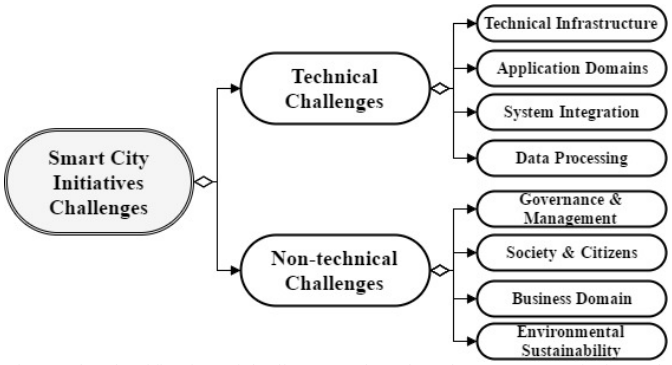

Fig. 1. The classification of the literature, based on the taxonomy of Yin et al. [68]

In the following, each of these eight sub-domains will be discussed. Various papers focus on multiple technical or non-technical domains; therefore, the challenges and solutions will be discussed in the corresponding section.

A. Technical challenges

Intuitively, Smart City development is an endeavour aiming to integrating state-of-art innovation in the city. Incorporating innovations in the city's infrastructure is adverse and in the following subsections, the challenges are identified and the proposed solutions are discussed.

1) Technical infrastructure

Technical infrastructure defines the “technical aspects” [20] of how the individual components within the city are interconnected. These components can be humans operating their mobile devices, but also intelligent machines and computers. Technical infrastructure can be redefined as smart devices that are capable of Sensing, Understanding and Acting [8, 69] or Sensing, Awareness and Actions [7], which can be shared within the city to become a smart collective embodiment of interlinked devices. All three elements have the objective to supervise, act upon events in the city and to assign resources within the city. The data retrieved and processed by the “crowd of devices”, is the key pillar to attain awareness about what events are occurring in the city. However, a uniform data format is still absent within a vast infrastructure of various devices, which challenges the goal of integrating data sources to create this awareness [5, 15]. To overcome this challenge, the collective embodiment of smart devices should be self-descriptive [22]. These collective embodiments of interconnected smart devices are commonly referred to as “Superorganisms”, which serves to empower the individual elements by combining them [7, 8, 69]. These Superorganisms are inspired by ant communities, which have the natural ability to cooperate and coordinate collective actions [8]. Based on the volumes of sensed data and its ability to process the data, Superorganisms are automatic computing [22] entities that covers human-human communication, human-computer interactions (HCI) and machine-to-machine communication (M2M) [60], meaning that they are anywhere-anytime. Superorganisms aim to overcome heterogeneity and interoperability of data sources, creating awareness and they dynamically address existing issues within the city. Superorganisms can overcome these challenges by first, observing their own status, thus being aware of their own self-* properties (e.g. self-adaptation and self-organization among others) [22] to overcome interoperability. Second, Superorganisms need to able to re-configure themselves by learning (Machine learning) [7] and scalable to assign needed resources [61]. Semantic systems such as so called \Live Semantic Annotations" (LSA) embed contextual awareness, the above mentioned self-* properties and controlling behaviour mechanisms on an individual level to coordinate collective actions [8]. An example of these Superorganisms is the EU-funded SAPERE project [8]. As Superorganisms heavily depend on the ability of vast infrastructures of devices to communicate with each other, the challenge is to create a resilient communication interface. However, common interfaces such as Wireless Fidelity (WiFi) are faced with interference, wall penetration adversities and variable bit-rate issues [39]. Technologies such as ZigBee networks and Bluetooth devices (BT-LE), aim to mitigate signal interference by subdividing the communication spectrum and combining windowing and cancellation carriers but, lack the ability to attain sufficient bit-rates. Moreover, the alignment of communicating devices within buildings serve to mitigate wall penetration challenges. To attain sufficient bit-rates, Cognitive Radio (CR) is proposed as the solution to overcome these three communication issues in Smart Cities [39]. But, Cognitive Radio is not yet available for commercial usage and therefore, the question remains which communication medium is the best bet.

2) Application domains

The application domains define the different Smart City Goals (SCG). These domains are urban planning, mobility, and healthcare, amongst others [20, 30]. The vision on Smart Cities is often focussed on multiple domains, which requires initiatives to address cross-thematic issues. More than the cross-thematic issues, domains do also consider heterogeneity services. which makes it averse to integrate single-purpose solutions. An example of this heterogeneity is the SMART mobility application [19], since it aims to improve different modes of transport (e.g. bicycle traffic flows and public transit) within one generalized solution. The challenge is to provide an abstraction layer on top of the technological innovations that addresses heterogeneity. The adversity of this abstraction layer is the incorporation of different sensing techniques to monitor and address service specific challenges, this is referred to as “service discretization” [28]. Jensen, Gutierrez & Pedersen identify that tracking individual vehicles as a service specific challenge which demands for a specific solution [28]. Homainejad proposes a single-purpose solution to this problem, which issues an image tracking sensor infrastructure or closed-circuit television (CCTV) installation [26]. Moreover, the availability of existing infrastructures conjointly issues specific

designed solutions, since the existing infrastructure determines whether solutions can successfully be integrated. For example, the absence of resilient WiFi communications in the third world demands educational services to reduce internet access time by caching information [42], indicating the inapplicability of alternative solutions such as Mobile Moodle (Momo), Mobile Learning Engine (MLE) and Moodbile. As specific solutions do not generalize well towards domain-level solutions, multiple studies call for developing generalizable architectures for technologies [20, 61] as well as for Smart City development [30]. The children's independent mobility (CLIMB) platform proposed by Gerosa et al. [20] is an example of an architecture that aims to provide an abstraction layer on top of service-specific solutions.

3) System integration

System integration defines the measures to integrate Smart City initiatives within the existing technological landscape of the city. The integration of smart solutions within existing technological landscapes requires considerable attention of system planning, since the environment within cities does not standstill [8, 20]. The dynamic environment demands integrated solutions to continuously adapt itself, which requires the system to be autonomous [22] and scalable to act upon changing needs of users. For a system to successfully integrate into existing infrastructures and to get adopted by it, systems should be able to cooperate and empower each other. On the one hand, open solutions are proposed to ensure successful integration [12, 20, 22, 24], because of the capability of tapping into each other's resources. Therefore, these systems gain more awareness to act upon. On the other hand, the coupling of different systems is key to successfully integrate new technologies [6]. The coupling of systems can be referred to as a "Joint-venture" of systems, helping each other to achieve their set goals independently. This key concept is illustrated in the literature regarding successfully integrating systems [12, 13, 15, 22, 24, 38, 51, 65], because orchestration of knowledge in the ecosystem of technologies enhances inter-solution collaboration. Before systems are adopted within an ecosystem, the usefulness of the systems should be evaluated. Whenever, a system can illustrate its enhancing impact on the city's infrastructure, it is more likely to get adopted. To that extent, promoters of Smart City initiatives should not be hesitant to experiment and validate solutions within so called Living Labs (LL), such as discussed by Ståhlbröst, Bergvall-Kåreborn & Eriksson [56]. From a practical point of view, the integration of costly innovative installations is an attractive victim of theft (e.g. integrated sensors in garbage bins) due to its valuable components [67]. Due to this fact, Smart City promoters become hesitant to integrate their costly innovations. Investing in the integration of technologies serves to discourage petty criminals and therefore, mitigating increasing theft rates.

4) Data processing

The data processing domain defines how Smart City solutions and their associated sensors collect, process and disseminate data to improve urban performance. Big data, also referred to as big, open and linked data (BOLD) [51], is a key pillar serving to improve urban performance, since it contains the needed information to understand current city needs and act upon it. Big data is qualitative defined as generated data through processes of datafication of new ICT and the Internet of Things (IoT) that is readable for machines, computationally manipulable to enhance large-scale analytics [58]. Computer scientists commonly refer to the terminology of three V's to define Big data and these are; volume, velocity and variety [37]. These characteristic three V's are also the challenges for data processing technologies, since Big data collection requires technologies to combine data sources, demands for high computational power and storage capacity.

The variety of data sources has been identified as a key challenge to comprehend with Big data [7, 8, 20, 22, 30, 51, 58, 69], since the collected data is retrieved from heterogeneous sensors installed within the city with their own data formatted entries. Different formatted data entries, thus different types of data, challenges the contextual understanding of artificial intelligent entities [69]. To that extent, there are two proposed solutions identified in the literature and these are; the capability of machines to learn on the fly [7, 8] and the development of standardized architectures for sensors that use shared services for computational power and are connected via the Cloud for the storage of data [13]. An example of such architecture is the combination of Hadoop Distributed File System (HDFS) and the cloud-based database MongoDB [13]. The velocity of Big data requires technologies to be able to re-configure itself [7, 20, 69] to mitigate unknown data biases (e.g. demographic inequality) by detecting anomalies via predicting systems in real-time. An example of such system is the combination of Storm frameworks and Cumulative sum (CUSUM) algorithms [63] besides serving citywide interest [58].

B. Non-technical challenges

The coexistence of formal and informal aspects besides technical aspects [20] indicates the importance of balancing the two perspectives to successfully integrate Smart City innovations. In the following, the challenges of these formal and informal aspects are identified and proposed solutions in the literature are provided.

1) Governance & management

Governance & management defines the formal aspects [20] of initiatives aiming to achieve Administrative Modernization [51]. There are two distinctive perspectives towards governance regarding Smart Cities and these are; governance managing Smart City development and Smart City initiatives shaping governance. Regarding the first perspective, it is key for promoters to have a clear strategy [12, 25, 38, 50, 51, 58, 65]. Having a clear strategy serves to receive in-depth insights into stakeholders needs [12, 51, 65] and values [3]. Furthermore, strategies serve to define what the right Top-down or Bottom-up development topology is [3, 7, 8, 13, 25, 58, 69] for successfully governing initiatives. Regarding the latter perspective, it is key to understand which technologies shape governance, such as the availability of Big data does [12, 25, 51, 58, 65], and whom benefits from the integration of new systems in terms of power and control [3, 13, 15]. Having a clear strategy is an important measure towards successfully governing Smart City initiatives. These strategies help to focus on the citizen's needs [3], since local context specificity implies that one size fits all solutions do not hold for Smart Cities. Furthermore, strategies serve to maintain the alignment of stakeholder interests and visions [25, 65]. The challenge is to create a holistic perspective, which addresses local problems

instead of global ones [3, 28]. To that end, holistic strategies serve to resolve city-specific problems which is the obvious goal. Another challenge for Smart City initiatives is understanding how technologies are interconnected with their societal implications. To that extent, promoters should have both technical and business knowledge to understand these implications [12, 61]. Moreover, an analysis of all the involved stakeholders is required to draft successful strategies. Strategies should address the values and the motives of the stakeholders have and the design choices of the respective system that are aligned with these values. For example, van den Berg and Viaene define an ecosystem of roles that are important to be aware of in smart city initiatives [65]. The ecosystem identifies whether systems must be designed in a top-down or a bottom-up way. Therefore, the roles of the stakeholders define this governing topology.

Visions of Smart Cities are challenged by the influence of integrating new technologies on the governance and management topologies [12, 25, 51, 58, 65]. The adversity stems from the question of whom benefits from the integration of ICT. Commonly, the integration of ICT results in an increasing influence on governance and power for the private sector and businesses (e.g. IBM and Cisco [23]). The changing governance landscape has been deemed a key challenge to resolve and it identifies what impact it holds on the view of Smart Cities in terms of politics of control, institutional architecture and governance specificity [3, 13, 15]. The key measure to overcome these challenges is for governments to draft new laws retaining the accumulation of influence and power of a single party, since governments are eventually responsible for the city [12, 65]. These laws serve to balance the power of the various parties by, for example, obligating the data sources to be shared [3]. Scholl & Al Awadhi propose a "Three Houses" framework [51] which serves to enhance inter-party collaboration and balances power and influence among the different agencies.

2) Society & citizens

Society & citizens define the informal aspects [20] of Smart City initiatives aiming to address the needs of the society and is referred to in the literature as Citizen Science [30]. The challenge within this domain is to persuade societies to adopt new technologies into the fabric of their everyday life. This challenge contains citizen awareness, security, privacy, trust, health and ethical aspects [12, 30, 47, 51, 65]. Citizen participation is key to overcome these challenges and to achieving societal adoption [6, 15, 20, 30, 38, 51, 67], since it implies a change of behaviour of the citizenry towards being proactive. Open software and documentation [51], empowers citizen's awareness, feeling of security and privacy, and trust. Therefore, persuading citizenry to get involved in the Inclusive Governance of solution developments as prosumers [30]. In contrast, persuading citizens to participate in the development of Smart City initiatives is not straightforward, since the integration of systems directly changes the dynamics of the society's ecosystem. Whenever citizens understand the technicalities of the embedded systems, a feeling of being monitored can arise on the horizon. The referred to ethical concept of Bentham's Panopticon [40] strangles the citizen's feeling of security, privacy and trust [58, 59], which results in the adversity to convince them to participate in the development of Smart Cities. Furthermore, ethical dilemmas of equity and fairness endangers the participation of citizenry, since unknown and demographical biases within the retrieved data are difficult to recognize for researchers whom therefore, have the illusion of 'complete' data [58]. Moreover, the hampering "Status Quo" [51, 65] attitude of citizens endangers the successfulness of system integration, since this attitude lacks the motivation towards innovation. Therefore, innovations should contain an intrinsic or extrinsic benefit for the citizens to adopt these innovations. The SMART mobility application [19], for example, integrates an incentive-based rewarding system for the better of integrating the system. Zambonelli likewise identifies that incentives serve to persuade citizenry to participate in Smart City initiatives [69]. Gerosa et al. proposes gamification to achieve citizen participation. However, gamification techniques are divers and in given situations still complex and costly to implement. Therefore, Gerosa et al. indicate that there is a need for certain gamification platforms and tool sets, which enable easier gamification development in a shorter period whilst avoiding large investments [20].

3) Business Domains

The business domain defines the disciplines of finance, budgeting and power in the context of Smart Cities. Incorporated in the vision of integrating ICT innovations, is the motivating prospect of improving economic growth. Nonetheless, how to benefit from Smart City initiatives continues to be an elusive question. The challenge within this domain is identified as how to improve the fiscal and budgetary disciplines [51]. Business support systems [38] serve to frame these disciplines to get a grasp on business opportunities. However, still the questions remain whether the benefits outweigh the costs, whether the financial opportunities for the Smart Cities is the foremost driving motivation for the different stakeholders and to that extent, whether the financial opportunities align among the different stakeholders within the strategy towards being a Smart City.

First, Smart City initiatives require large upfront investments to get integrated within societies [67]. The benefits of these initiatives should outweigh the expenditure taken in advance. Businesses can become hesitant to invest in the plans of governments to become smarter. Business supporting systems [38] bolster the analysis of business opportunities to drive home financial investments. Yet, data is a financial asset and therefore, businesses are keen to keep the data to themselves. Resulting in the endangerment of open data services, which is required for the integration of. Second, technology companies are aiming to embed their solutions in the vision of the Smart Cities. Their motivation is to financially benefit from the embedding of their systems. However, the analysis whether their solutions align with the strategy of the governing agency of cities is left out. This results in the discussion whether these so called 'smart solution' are improving city infrastructure's smartness, such as Hatch questions in his research [23]. This research illustrates that there is a gap between the values of different stakeholders. The strategies of Smart Cities are therefore, required to align these values without them counter-interfering each other [25, 65], since realigning Smart City initiatives can be costlier than aligning values upfront.

4) Environmental sustainability

The domain of environmental sustainability defines the implications that initiatives have on the environment and how initiatives can support urban infrastructure. The integration of systems and the consequently required set of sensors results in increasing energy demands on a citywide scale. An increasing energy demand is inclined to pollute the environment even more than it is already endangered with. On global scale, national governments are collaborating to reduce greenhouse gas emissions by drafting global policies on climate change, such as in Kyoto (1997). However, Smart Cities need other measures to monitor and address rising levels of pollution [47]. While sensor-packed ICT systems are capable of monitoring urban performance, these sensors are likewise capable of monitoring waste, energy demands and can mitigate disasters by so called "Disaster management" systems. Disaster management systems can predict environmental disasters, which is a current global threat to Smart City solutions because it disrupts IT operations. Monitoring environmental changes are key to predicting environmental disasters [47, 56] and to that extent ICT improves Smart City resilience [31]. Therefore, the challenge is also to be able to monitor drastic environmental changes and to make an accurate prediction of its associated consequences to act upon it by having emergency management systems in place. This means that the identified three components Sensing, Understanding and Acting [8, 69] are vital to making these predictions.

First, waste management systems, such as Dynacargo [67], aim to monitor waste levels and anticipate as efficient as possible by integrating sensing devices, such as Radio-frequency identification (RFID) technologies [67]. Nonetheless, these solutions do encounter complications induced by weather conditions, which can cause sensors and systems to malfunction. By integrating environmental sensors in the system's design, the system can monitor environmental conditions and re-configure itself. Furthermore, architectures can help to mitigate malfunctions by proposing standardized system infrastructures [67]. Second, it goes without saying that the incorporation of ICT systems increases energy consumption despite of improving energy efficiency, which is theme to Green Computing practises. Nonetheless, the capability of responding to energy demands as well as the distributed generation of energy and storage are key for energy efficiency [69]. So-called Resource Management tools [43] enable systems to respond more efficiently to energy consumption. Whenever used energy is produced by fossil fuels (e.g. coal), it likewise increases greenhouse gas emissions besides increasing energy consumption. However, current practices mitigate rising levels of pollution by tapping into other energy sources which are durable and renewable. As current Smart City initiatives require significant amounts of energy, such as data centres storing the accumulated data [49], the importance of clean energy sources is stressed.

Moreover, IT becomes an important tool for monitoring the city's infrastructural components (e.g. buildings and roads) in recent literature. Sensor-packed systems and mobile devices serve to achieve better infrastructural sustainability [17]. The need of innovative IT solutions for monitoring the civil infrastructure of the city is depicted in a recent study of Forman on the imminent threats of decaying networks, buildings and roads in New York City on its sustainability [16]. Aging urban infrastructures are increasingly pressured by the increasing demand of citizenry in the city. Therefore, not only maintaining of the aging infrastructures is under pressure but also its fitness to current urban demands. Thus, besides that ICT systems serves to reduce pollution, it also becomes increasingly important as tool to stay ahead of environmental disasters caused by aging urban infrastructures of brownfield Smart cities.

VI. Framework development

As global societies head towards new cities of intelligence, countless businesses and governments are aiming to create Smart Cities. As identified in the previous section, these initiatives are challenged with adversities in practise. So, the hefty concern identified in this work now is how to address these challenges to ensure successful integration. This section proposes a requirements framework that rather depends on the reader's re-thinking of how to conduct Smart City initiatives by providing a check-list of key factors for promoters than taking promoters by the hand. This section validates the findings of the literature study by studying the case of Enschede by means of an interview with a Smart City project manager, Mrs. Looman, working with the municipality.

A. Key factors for smart city Enschede

Smart Cities, according to the interviewee, is a challenging topic, due to the tendency of promoters to consider the technical aspects [20] as more important than the formal and informal aspects. However, addressing Smart Cities kicks-off with the primary question what the key problem within the city currently is. The current problems of urbanization define what is needed from within city's society, meaning that current problems likewise determine what solutions will imply smartness. Enhancing the municipality of Enschede has been focussing on mobility, durability and safety. Future plans are to align these three topics with the integration of WiFi devices within the city to monitor events via these WiFi devices. The interviewee foresees a key role for Big Data, as she rather refers to as Better Data or Business Intelligence due to ethical limitations of data usage, to achieve societal participation. Transparency of Smart City solutions are the primary enabler for societal participation, which is a key factor to successfully integrating technologies within city infrastructure, but it also serves to re-configure urban governance, because transparency presumably enhances citizen awareness. Therefore, so called e-governance is aimed for in the future of Enschede.

Incorporated in these opportunities are challenges that should be addressed in the strategy of the policymakers. The interviewee identifies several challenges and these are; i) marketing Smart City initiatives, which serves to improve societal adoption by informing citizens through Smart City conventions [9]. ii) Inter-platform collaboration, which aims for systems that are mutual beneficial and interrelated by making use of shared assets (e.g. data) as is done for the SMART mobility application in Enschede, Brabant and Amsterdam [19]. iii) The multifaceted challenge of governance of information and ownership within e-governance, and the necessity of experimentation. First, it is important to introduce legislations

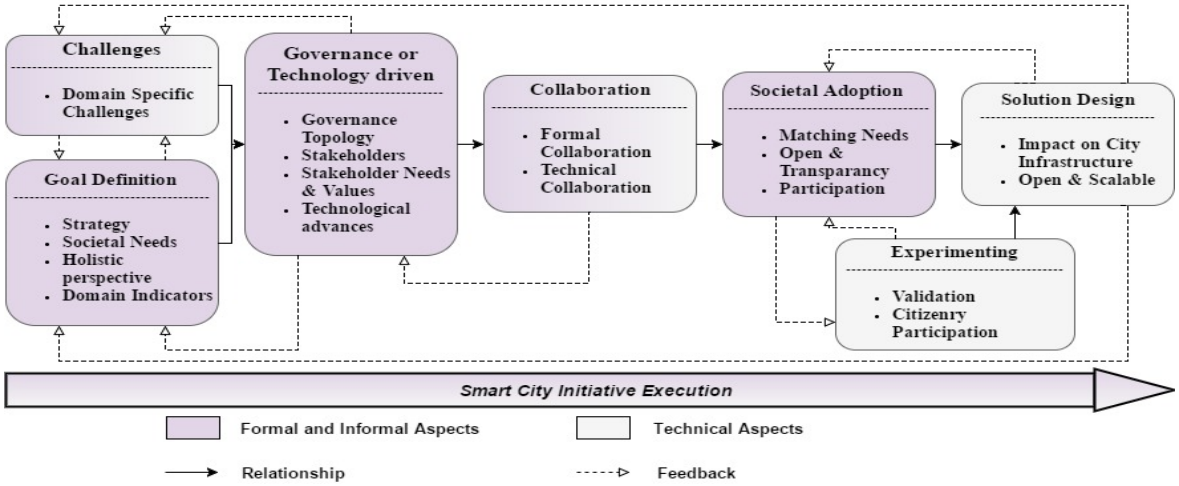

Fig. 2. The Requirements Framework for Smart City Success

to disallow information monopolies threatening privacy, security and the values of society. Current laws are outdated and do not translate to the changing character of ICT innovations, indicated by the third cyber-security act in the Netherlands. Second, necessity exists to incorporate information ownership within the strategy aiming for smartness. Municipalities should understand the consequences of outsourcing data analysis on the role of governance of municipalities. The ability of cities to conduct experimental pilots of ICT innovations is also key for societies to adopt new technologies as is achieved by partnering with Saxion, University of Applied Sciences, and the University of Twente [64].

B. Communalities found in this study

A variety of common identified challenges is found in the literature and the field study. First, the importance of identifying and analysing the current problem of the city is stressed by both sources, since one size fits all solutions do not hold for cities aiming to achieve smartness. Therefore, necessity exists to recognize the needs of the city from a holistic point of view [3, 28]. Second, the key role of open and scalable solutions is identified by the two sources. As coupling of technologies [6] serves to benefit from the collaboration of promoters, the data and architectures of systems should be openly accessible to improve urban management. As identified, inter-connected systems can address encountered challenges of societal adoption by learning from each other. Third, the position of governance is vital whenever considering Smart City developments as innovations drive governance towards new structures (e.g. politics of control [58]) by means of emerging communication media. How to manage technologies shaping governance structures, is the challenge to address on local societal scale. Last, the literature identifies the necessity of experimenting with new technologies by means of so called Living Labs [56]. The interviewee acknowledges the vital role of experimenting which serve to attain feedback and therefore, to achieve higher societal adoption.

C. Smart city framework for success

Based on the literature review and the findings from the field study, this section proposes a requirements framework for successful Smart City initiatives in Figure 2. The framework rests on the concepts discussed in the previous sections. These concepts are; challenges a city faces, the goal definition of enhancing the city, whether initiatives are governance or technology driven, collaboration types between different promoters, societal adoption of initiatives by citizenry, solution design of Smart City plans and, experimentation.

The framework treats Smart City initiatives as complex social and technical endeavours where gaining mastery of both formal and informal and, technology aspects is key to be able to successfully integrate IT innovations. The concepts are mapped unto these two aspects to illustrate their inter-relatedness, since the combination of both aspects depict the complexity of Smart City initiatives. The framework depicts a logical stepwise path of influence from identifying specific Smart City challenges and goals towards the design of fitting Smart City solutions.

The execution of Smart City initiatives can either be governance or technology driven, the framework therefore views both drivers as equally useful since the case study showed that both drivers can result in Smart City success.

Societal adoption is a key factor for success as indicated in the literature as well as the case study therefore, it plays a central role in the framework interplaying with the concepts of promoter collaboration, influencing societal adoption through showcasing best practices, and experimentation with prototypes to show citizenry 'what is in it for them' to stimulate adoption.

Eventually, promoters can drive the execution of initiatives home by proposing a solution design after undertaking the consecutive steps by following the above-mentioned relationships between the different concepts. Coming to a solution design is not a one-way street and in the framework, the importance of the feedback between the concepts is underlined. After the execution, promoters may question whether the solution design treats their identified challenges and accomplished their initial goals. To that extent, the consecutive steps reflects on the previous step to stay in touch with the needs of the city and its citizenry by defining relational feedback.

To provide additional guidelines to Smart City initiatives, A check-list of reflective questions, subdivided in various factors identified by this literature study and the case study, is proposed in Table 1 for promoters to validate whether they have thought of all key factors for success contained in these concepts. In the

TABLE I
CHECK-LIST OF VITAL QUESTIONS FOR SMART CITY SUCCESS

Component	Questions
Goals	1. Does the promoter have a strategy?
	2. Does this strategy consider societal needs of the community?
	3. Does this strategy align with targeted domain level indicators [14]?
	4. Is this strategy drafted with a holistic perspective?
Challenges	1. Does the initiative address domain specific challenges (e.g. Open data and demographic biases)?
Governance	1. Are all Stakeholders identified for this initiative?
	2. Does the promoter consider all stakeholders' needs and values?
	3. Does the initiative fit into current Smart City practices and maturity level of the promoter on Smart Cities?
	4. Does the initiative consider the right topology of governance on initiative level (Top-down or Bottom-up)?
Collaboration	1. Does the initiative consider technical collaboration of similar systems?
	2. Does the initiative consider formal collaboration of the different stakeholders?
Societal Adoption	1. Does the system address the needs of the communities?
	2. Does the initiative adopt open & transparent designs?
	3. Does the society participate in the designing stages?
Experimenting	1. Does the experimenting phase validate the design choices?
	2. Does the experimenting phase achieve citizens' willingness to participate?
Solution Design	1. Does the solution have an improving impact on the city's infrastructure?
	2. Is the solution an open & scalable service?

framework, these factors are also depicted to position them during the execution of Smart City initiatives.

VII. Discussion

During this research, it has come to light that the in-depth study of the attained literature, the classifying among the eight different sub-domains and drafting the requirements framework took more effort than anticipated. The fact that papers often discuss multiple sub-domains with its own unique interconnections based on the purpose of the paper, implied that the papers had to be studied in greater detail to gain more insights into used terms, terminology and overlapping sub-domains besides differences in language and writing styles. Furthermore, generalizing the findings of the field study also required more in-depth insights into the identified challenges.

As indicated in Section V, it was adverse differentiating the eight sub-domains based on their primary addressed topic in the papers. A variety of papers discuss multiple subdomains in some degree. So, every paper discussing multiple interconnected sub-domains with paper thin boundaries has been discussed in the different sub-domains. Observed in the papers is the absence of thorough research into the sub-domains of Business Opportunities and Environmental Sustainability. One reason of this could be that these sub-domains are less interesting to study, since Smart Cities attract lots of attention towards the technical aspects besides the straightforward business opportunities and implications of technologies on environmental sustainability. Yet, due to the exclusion criteria narrowing down the scope of searching for literature within the field of computer science, it could be that these sub-domains may be a topic of study in other fields of expertise.

The aim of the framework is to support promoters. However, this framework can work out differently for the different levels of maturity of promoters. It is necessary for promoters unfamiliar with the domain to establish a clear strategy first. Whenever promoters become familiar with the domain and its practices, it is important to align future initiatives with their strategy. The framework does not decide whether (in)formal aspects are more important than their technical counterpart, thus promoters should determine for themselves whether governance shapes the initiatives or initiatives should be technology driven. This illustrates the purpose to set promoters to (re-)think their initiatives.

A. Limitations

This work has the following limitations. First, concerning the systematic review, our search was limited to the Scopus database. Next, the language of literature is limited to English, which might mean that our list of included papers is incomplete. However, we think this risk is reduced since most Smart City initiatives are international and promoters publish their most important results in English. Second, concerning the field study, the fact that we focused on one government-driven Smart City endeavour implies limited generalizability. Other cities may well encounter other challenges while working similar initiatives. As Enschede currently aims to enhance mobility and its centre's infrastructure, this field study does not reflect the variety of Smart City initiatives. In turn, our results could be considered as indicative only. More case studies are therefore necessary. Third, concerning the check-list, we think that it could be possibly generalizable across various context, as it was derived based on the case study in Enschede and on the case studies described in the reviewed literature. As methodologists suggest [52], including multiple sources of case study data improves the external validity of an artefact such as the check-list. However, to know this, more research is needed to provide more empirical findings from other Smart City contexts beyond those published.

VIII. Conclusion and Future Work

This section presents the answers to the research questions that were investigated by jointly using literature review techniques and case study research. After this, we discuss some implications for researchers and practitioners.

A. Answering the research questions

The answers to the research questions are as following:

RQ 1: *What challenges does the development of information systems for Smart City applications face according to recent publications (2008-2016)?*

Based on the taxonomy by Yin et al. [68], the challenges of Smart City development can be identified in eight subdomains, as stated in Section V: i) how technical infrastructures are build, ii) how to successfully integrate systems in the fabric of the city, iii) how to design solutions for specific application domains, iv) how to address the imminent volumes of data or big data, v)

how governance shapes innovations and how innovation shapes governance, vi) how citizenry is persuaded to participate in Smart City development, vii) how businesses influence Smart City visions
and lastly, viii) how Smart Cities influence environmental sustainability.

RQ 2: *How do current Smart City initiatives translate into a requirements framework, according to the field study in the municipality of Enschede and the case studies found in the literature?*

By gaining insights into the challenges of the eight subdomains of Smart City initiatives, the requirements framework attempts to provide a generalizable check-list of questions to guide the execution of initiatives in combination with defining the relationships of elements for initiatives. On the one hand, the framework does not aim to take initiatives by the hand, rather it attempts to set the promoters to think about the needs of their initiatives by setting out the right questions. On the other hand, the identification of relationships between the components serve to gain awareness of influencing factors towards an appropriate design of the solution.

RQ 3: *What solutions have been proposed to counter the challenges for Smart City Initiatives, according to published literature? And which of these challenges are still under-researched*?

The literature proposes eight solutions to the encountered challenges of Smart Cities: i) new technologies such as cognitive radio [39] overcome the difficulties to interconnect the different elements within the technical infrastructure of systems. ii) Open & scalable services and technical collaboration between systems serve to design architectures that improve system integration. iii) The understanding of application specific needs serves to better depict the architectures of solution [20]. iv) The capability to combine various data sources and processing different data formats is key to comprehend with the three V's of big data. v) Drafting strategies for the execution of Smart City initiatives is key to identify city needs and to address governance changes. vi) Gamification helps to persuade citizen participation by providing incentives for collaboration. vii) Business support systems help to support business motivations for the execution of initiatives. vii) Monitoring energy demands and creating energy efficiency serves to create environmental sustainability while integrating energy demanding systems in the city. Yet, as identified in Section VII, the topics of the business domain and environmental sustainability have not been frequently addressed in the literature, it should be said to that extent that environmental sustainability is an emerging trend in recent literature on how IT solutions can support urban infrastructures as tool for assessment. However, these two domains still are under-researched in the field of Smart Cities.

B. Future work

The results of this research identify that the proposed framework needs to be validated and that there is a gap in literature on Smart Cities. Within the scope of this research, it was not possible to validate the framework. Therefore, in the extension of this work, the framework needs to be validated within the endeavours of municipalities aiming for smartness. Follow-up studies should focus on evaluating the framework by practitioners working in the field. Only then, we could judge its applicability. Moreover, the under-researched topics of the Business Domain and Environmental Sustainability need extra attention to mature. These domains offer uncharted territory for researchers to come up with solution proposals and evaluate them in context.

C. Implications for practioners

This work contributes to the understanding of practitioners that conduct Smart City initiatives is challenging due to its multifaceted characteristics. By identifying challenges for Smart Cities and their proposed solutions in the literature, this work provided a requirements framework and a check-list that can possibly guide practitioners in reasoning about their Smart City initiatives and how to make them successful. Hopefully, this research makes promoters aware of the importance to think of all required technical, formal and informal aspects of Smart Cities.

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