A Framework for a Smart City Design:

Digital Transformation in the Helsinki Smart City

Mervi Hämäläinen

[1] University of Jyvaskyla, Faculty of Information Technology
P.O. BOX 35, FI-40014 UNIVERSITY OF JYVÄSKYLÄ, FINLAND
Mervi.a.hamalainen@jyu.fi
Mobile: +358-40-1907163

Abstract. Recently, there has been substantial interest in the concept of a smart city, as it has been a viable solution to the dilemmas created by the urbanization of cities. Digital technologies—such as Internet-of-Things, artificial intelligence, big data, and geospatial technologies—are closely associated with the concept of a smart city. By means of modern digital technologies, cities aim to optimize their performance and services. Further, cities actively endorse modern digital technologies to foster digitalization and the emergence of data-based innovations and a knowledge economy. In this paper, a framework for a smart city design is presented. The framework considers a smart city from the perspective of four dimensions—strategy, technology, governance, and stakeholders. The framework is complemented with sub-dimensions, and the purpose of this framework is to strengthen the governance and sustainability of smart city initiatives. Further, the proposed framework is applied to the Helsinki smart city, the capital of Finland. The objective is to analyse the Helsinki smart city through dimensions presented in the framework and learn how the city of Helsinki governs and implements its smart city initiatives.

Keywords: Smart city, digital technology, strategy, stakeholders, open data, technology experimentations

1 Introduction

Cities are lucrative areas for economic growth, as 80% of the current global GDP is produced in cities (Dobbs et al., 2011). This trend is likely to continue as urban areas already provide homes to over half of the world's population, and the number is estimated to increase by 66% by 2050. In addition to economic wealth and prosperity, urban areas offer more versatile job opportunities and alternatives for advanced education. Further, urban areas also provide conducive environments for new innovations and businesses. The reverse side of urbanization and improved prosperity is an increased volume of consumption, waste, and pollution. According to UNEP (2013), over 75% of the world's energy and material flows are consumed in cities. Along with

rapid urbanization, cities are likely to consume even more natural and non-renewable materials, as urbanization sets demands for the construction of new residential areas and improving city infrastructures and services. As an example, cities must renew and build transportation, energy, and sewer network infrastructures and systems, as well as build new premises for hospitals, schools, and day care centres to guarantee fulfilment of their mandatory functions. It is also worth noting that increased population itself consumes more natural and non-renewable resources to satisfy basic necessities and accomplish the desires and purposes of individual human life. It is emphasized that local city governments place strategic focus on sustainable and resource-efficient urban development. It is highlighted that cities must design denser urban areas and invest in modern low-carbon infrastructure solutions. Further, existing studies also argue that the shift from traditional carbon-intensive infrastructure to low-carbon infrastructure alternatives require a 5% increase in infrastructure investments in cities. Thus, cities must have improved abilities to effectively manage resource flows and enhance resource efficiency by focusing on smart land use and investing in modern urban digital infrastructures (IRP, 2018).

The concept of a smart city has been a popular phenomenon, and multiple cities worldwide have adopted smart city practices in urban development. Further, information and communication technologies (ICTs) and novel digital technologies such as Internet-of-Things (IoT), artificial intelligence (AI), and data analytics play an integral role in the implementation of the concept of a smart city. The European Union (EU) defines a smart city as 'a place where traditional networks and services are made more efficient with the use of digital and telecommunication technologies for the benefit of its inhabitants and business'. Alternatively, a smart city is defined as 'a city, in which ICT is merged with traditional infrastructures, coordinated and integrated using new digital technologies' (Batty et al., 2012). Caragliu, Del Bo, and Nijkamp (2011) define a city as smart 'when investments in human and social capital and traditional (transport) and modern ICT communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory government'. The ITU-T Focus group (2015) and ISO (2015) summarize that a smart city is an innovative city that uses ICTs to improve the quality of life of residents, thereby enhancing the efficiency of urban operations and services and improving sustainable socio-economic and environmental outcomes by responding to the challenges of urbanization.

The objectives of smart city initiatives and the use of digital technologies enable the streamlining of city processes and not only make city services more accessible for residents but also enhance the resource management and efficiency within the city (Aguilera, Peña, Belmonte, & López-de-Ipiña, 2017). Further, smart city practices aim to reduce the costs of city services and improve the return on investments (Vilajosana et al., 2013), accelerate economic growth, competitiveness and transparency, as well as stakeholder participatory in the cities (Abella, Ortiz-De-Urbina-Criado, & De-Pablos-Heredero, 2017; Perez, Poncela, Moreno-Roldan, & Memon, 2015; Yo-

vanof & Hazapis, 2009). New digital technologies applied in 'soft' city domains such as education, health and social care, and city administration (Petersen, Grazia & Oliveira, 2015) aim to foster knowledge creation and enable the emergence of new knowledge-based businesses and digital innovations (Baccarne, Mechant, & Schuurman, 2014; Li, Nucciarelli, Roden, & Graham, 2016). Smart city initiatives also aim to enhance social inclusion and prevent inequality among the citizens.

Deploying novel digital technologies across an organization's activities is a long-term process that impacts an organization's structures, capabilities, and existing IT infrastructures and systems (Davenport & Westerman, 2018). Thus, the design, management, and governance of digitalized and interconnected smart city operations and ecosystems are not a trivial task. Research has identified that numerous smart city initiatives tend to fade away when project funding is used (Diaconita, Bologa, & Bologa, 2018; Hämäläinen & Tyrväinen, 2016). The objective of this paper is to shed light on the elements that are relevant for robust digital transformation, ecosystem creation, and orchestration in a smart city. In order to achieve this objective, this paper presents a smart city design framework, which is derived from prior literature in the area of smart cities and smart city ecosystems and is adapted from the smart city conceptual model (SCCM) presented by Hämäläinen and Tyrväinen (2018). The smart city design framework is founded on four dimensions—strategy, technology, governance, and stakeholders—and is complemented by sub-dimensions. The smart city framework aims to improve the process of digital transformation within the city and assist smart city stakeholders in the private and public sectors to clarify complex smart city governance, ownership, orchestration, and decision making procedures. The framework also highlights the importance of technological compatibility, appropriate skills, and resource allocation in smart cities in order to ensure robust and well-grounded smart city implementation. In this paper, the smart city design framework (Hämäläinen & Tyrväinen, 2018) is applied to analyze the smart city of Helsinki in Finland through the abovementioned four dimensions and learn about smart city practices and implementation in Helsinki.

The remainder of this paper is structured in the following manner: Section II presents the principles of the digital transformation within organizations. Section III delves into the conceptual foundation of the smart city design framework, and Section IV covers the research methodology. Section V discusses the specific case of the Helsinki smart city and evaluates smart city initiatives in Helsinki through the smart city framework. Section VI summarizes the findings, and Section VII concludes the paper.

2 Digital transformation

Digital transformation is perceived as a paradigm shift (Berman & Marshall, 2014) resulting in 'changes that the digital technology causes or influences in all aspects of

human life' (Stolterman & Fors, 2004). Digital transformation is also understood as 'technology-induced change' (Legner et al., 2017) that may have radical or disruptive features (Morakanyane, Grace, & O'Reilly, 2017) that revolutionize prevailing practices by disrupting the trajectories of established businesses, and change the structures of industries and value networks (Au et al., 2018; Gimpel et al., 2018; Weil & Woerner, 2015). Digital technology evolution is all the more embedded in social areas (Legner et al., 2017; Tilson, Lyytinen, & Sørensen, 2010) and is driven by individual persons (Legner et al., 2017), which makes digital transformation with digital technologies a complex and uncertain process (Hess et al., 2016; Sahu, Deng, & Mollah, 2018). Since digital technologies have ubiquitous impacts on organizations and industry functions, it is emphasized that *a strategic focus* must be placed on how to conduct long-term digital transformation (Chanias & Hess, 2016; Henriette, Feki, & Boughzala, 2016; Hess et al., 2016; Legner et al., 2017; Matt, Hess, & Benlian, 2015; Ross, Beath, & Sebastian, 2017; Sebastian et al., 2017).

IT strategies are traditionally developed to manage IT infrastructures, tools, applications, and IT services (Gerster, 2017; Hess et al., 2016) that support an organization's functions and processes (Teubner, 2013). Differentiated from IT strategy, it is suggested that a specific *digital strategy* must be created that assists organizations to reflect on business perspectives and consider the resources, capabilities (technical and human), and financial aspects that are required in digital transformation (Bharadwaj et al., 2013; Matt, Hess, & Benlian, 2015; Mithas, Tafti, & Mitchell, 2013; Ross et al., 2016). Digital strategy evaluates the influence of digital technologies on the structures and process of organizations and observes possibilities for new business models and value creation among existing and new stakeholders (Bharadwaj et al., 2013; Morakanyane, Grace & O'Reilly, 2017; Hess et al., 2016; Legner et al., 2017; Matt, Hess & Benlian, 2015; Prince, 2017; Rauch, Wenzel & Wagner, 2016; Ross et al., 2016; Sebastian et al., 2017; Singh & Hess, 2017). Thus, digital strategy is a holistic view for top management to evaluate, manage, and govern the digital transformation journey (Chanias & Hess, 2016).

3 Framework for a smart city design

Along with heterogeneous stakeholder groups from private and public sectors, the city must perform its statutory tasks and activities around the clock without interruptions. A holistic overview of how a city transforms itself to a smart city and how digital technologies are applied in diverse city domains is needed. In the following account, a framework adopted from Hämäläinen & Tyrväinen (2018) is presented (Fig 1). The framework contains four central dimensions—*strategy, technology, governance, stakeholder*—and other sub-dimensions. The strategy dimension considers as-

pects of a smart city's vision, strategy, and capabilities. The technology dimension discusses the digital technologies applied in smart cities, as well as the data, technology experimentation, security, and privacy issues. Vertical and horizontal scopes conclude the technology dimension. The governance dimension describes the orchestration of the smart city stakeholders and ecosystems and considers funding and metrics to evaluate smart city performance. Finally, the stakeholder dimension elaborates on stakeholders and stakeholder value in smart city ecosystems.

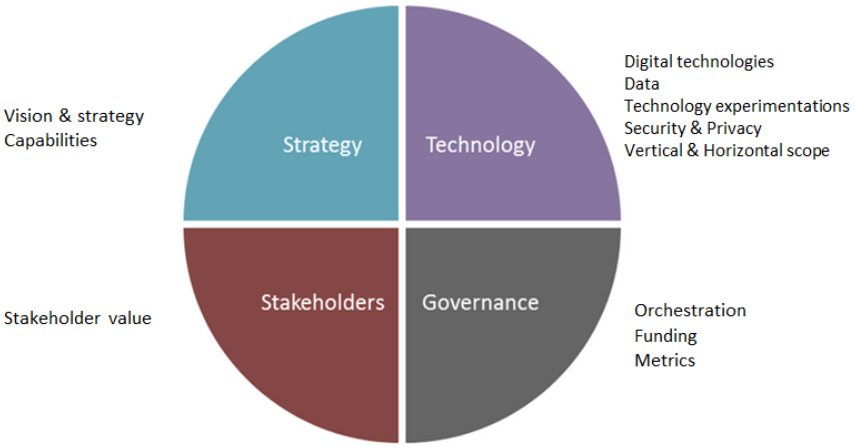

Figure 1 Framework for Smart City Design (adopted from Hämäläinen & Tyrväinen, 2018).

3.1 Strategy

Cities operate under a constantly evolving environment, which puts pressure on the city's governance and management. The strategy for a digital or smart city identifies the changes that occur in both national and global political, legislative, and economic landscapes, and also considers the impact of social and technological changes. As contemporary urban development relies on modern digital technologies (Lu, Tian, Liu, & Zhang, 2015), smart city vision and strategy envisions the future state of the city by means of digital technologies. Smart city strategy sets strategic guidelines on how a city must develop and integrates digital technologies to diverse urban infrastructures in order to enhance sustainable city design and performance (Hämäläinen & Tyrväinen, 2018). From a broader perspective, the smart city strategy also considers the impacts of climate change and evaluates the manner in which digital technologies can be employed to enhance material usage and reduce emissions within the city.

(a) Capabilities

Smart city strategy considers the goals, resources, and capabilities required for the successful implementation of creating a smart city (Scuotto, Ferraris, & Bresciani, 2016; Tillie & van der Heijden, 2016). The resources and capabilities of a smart city refer to both technical (Sarma & Sunny, 2017; Schleicher, Vögler, Inzinger & Dustdar, 2017) and human capabilities like knowledge to manage smart city design and orchestrate innovative data-based smart city ecosystems that create value for its stakeholders (Abella et al., 2017; Baccarne et al., 2014; Komninos, 2011; Komninos, Pallot, & Schaffers, 2013; Scuotto et al., 2016; Tillie & van der Heijden, 2016).

3.2 Technology

(b) Digital technologies

Emerging digital technologies such as IoT, AI, cloud computing, big data, and data analytics are rapidly expanding in urban areas, thereby creating multifaceted digital and data ecosystems (Aguilera et al., 2017). Schleicher et al. (2017) call smart cities 'data behemoths'. Rapidly increasing online city services, ICT connected city infrastructures and fast adoption of internet-connected technologies like sensors, video surveillance and lightning systems are applied in diverse city infrastructures. Applying modern smart city technologies to diverse smart city infrastructures helps to accumulate exponentially historical and real-time data from heterogeneous city domains and activities (Rathore et. al., 2018; Schleicher et al., 2017). Further, positive experiences from cloud computing have encouraged cities to invest on 'pay-as-you-go' cloud computing solutions. The collection of cloud computing components such as infrastructure-, platform-, and software-as-a-service provide new dimensions for more affordable, scalable, and easily available ICT service provisions for cities. One of the main characteristics for cloud-based service provisions is that the user is charged only when using the platform or service (Hernandez, Larios, Avalos, & Silva-Lepe, 2016; Petrolo, Loscri, & Mitton, 2017). Moreover, scalability and cost efficiency are the undoubted advantages cloud computing provides for cities.

(c) Data

In recent years, cities have released city data sets such as geographical and location information for public use. Open city data is not only used by the city's government, but also other stakeholders such as citizens, application developers, and third party organizations that exploit open city data for personal or public purposes (Aguilera et al., 2017). However, legislation like the *General Data Protection Regulation (GDPR)* in Europe prohibits and prevents cities from publishing data that is sensitive and criti-

cal from privacy and safety perspectives. High volumes and velocity of the city data add demands related to data management. Capabilities to process and analyse the city data are needed so that the data is useful for actors in smart city ecosystems (Khan et al., 2017; Rathore et al., 2018). Along with human capabilities, data engineers and scientists, technologies such as data analytics and AI speed up data processing and enhance data integrity and accuracy (Srivastava, Bisht, & Narayan, 2017). In the smart city settings, AI has been used to analyse data from video surveillance cameras and drones, which keep an eye on city environments and surroundings (Srivastava, Bisht, & Narayan, 2017).

(d) Technology experimentations in smart cities

The International Resource Panel (IRP, 2018) emphasizes that cities must develop and apply urban experimentation policies. Cities certainly have environments that offer multifaceted domains for diverse smart city technology experimentations. Technology tests and experimentation platforms (TEP) such as testbeds, innovation and living labs, and prototyping platforms have been dominant facilities for smart city technology and service development and experimentation (Ballon, Pierson, & Delaere, 2005; Schaffers et al., 2011). Heterogeneous urban domains offer numerous advantages for technology experimentations. For smart city practitioners, real world city-level experiments not only enable iterative technology and service development but also provide access to collection of data from real users. During smart city experiments, developers receive valuable information on product usability and developers may simultaneously validate feasibility and user acceptance of smart city technologies and services (Hämäläinen & Tyrväinen, 2016). Ten relevant dimensions for establishing robust smart city technology experimentation platforms have been identified. These dimensions are openness, real-world experiments, user/public involvement, vertical and horizontal scope, scalability, sustainable value creation, continuity, IoT/data heterogeneity, and system architecture design. These dimensions prove to strengthen the emergence of the smart city ecosystem and the duration of smart city TEPs (Hämäläinen & Tyrväinen, 2016).

(e) Security and privacy

Information systems are applied to almost all fields in our societies and emerging digital technologies are an integral part of smart city initiatives. A disadvantage of the ubiquitous cyber-physical systems is that there is an increase in the potential for security and privacy vulnerabilities. The term cyber security is defined as ‘the protection of cyberspace itself, electronic information, ICTs that support cyberspace, and the users of cyberspace in their personal, societal and national capacity, including any of their interests, either tangible or intangible, that are vulnerable to attacks originating

in cyberspace' (Von Solms & Van Niekerk, 2013). However, the more the frequency of application of digital technologies in smart city infrastructure, the greater the potential for vulnerabilities and data breaches. Thus, security and privacy themes must be placed at the top level in smart city development.

(f) Vertical and Horizontal scope

Many smart city initiatives focus on improving certain city verticals such as transportation or energy. Emphasizing certain verticals in smart cities may influence the choice of employed technologies and standards that best support the needs and requirements of a particular vertical industry (Hämäläinen & Tyrväinen, 2016). According to Schleicher et al. (2017), city data is isolated and restricted to exist in silos. If smart city development focuses only on a particular vertical, it may prevent more extensive technology and data adoption and exploitation in smart cities (Hämäläinen & Tyrväinen, 2016), thereby resulting in the emergence of data silos. Schleicher et al. (2017) emphasize the prevention of the emergence of data silos in smart cities by enabling ubiquitous access to heterogeneous and interconnected city data. *Horizontality* in the context of a smart city context implies how a wider set of data from multifaceted city domains and activities are collected, combined, and utilized. The horizontal approach contributes to a broader set of city data and expands the possibilities of creating new services based on integrated data in smart cities (Hämäläinen & Tyrväinen, 2016).

3.3 Governance

Growing markets in a smart city attract various organizations and stakeholders from private and public sectors. Smart city governance could be defined as 'the sum of the many ways individuals and institutions, public and private, manage their common affairs' (Commission on Global Governance, 1995). Smart city governance consists of multifaceted organizations, processes, and stakeholder relations; it also deals with legislations and policies (Ruhlandt, 2018). Moreover, smart city governance is a body that envisions the future state of the smart city, provides strategic leadership and resources, ensures dialog and decision making in smart city ecosystems, and assesses the performance of a smart city and the quality of its citizens' lives. (Baccarne et al. 2014; Recupero et al., 2016; Tillie & van der Heijden, 2016; Veeckman & van deer Graaf, 2015.) Further, smart city governance considers long-term financial needs (Vilajosana et al., 2013) to ensure robust and long horizon smart city implementation (Komninos, Pallot & Schaffers; 2013) as well as to reduce costs and improve resource efficiency in a city (Díaz-Díaz, Muñoz, & Pérez-González, 2017).

(g) Funding and Metrics

Major (upfront) investments are needed to successfully deliver smart city initiatives (Vilajosana et al., 2013; Díaz-Díaz, Muñoz, & Pérez-González, 2017). In European settings, digital urban development is one of the priority agendas and smart city funding is allocated through the EU to improve infrastructure—such as transport and water networks and waste management—as well as to improve the energy efficiency of buildings (European Commission). Globally, international organizations (e.g. United Nations Industrial Development Organization, UNIDO) provide funding for sustainable environmental development, such as green industries, sanitation, and waste management (Adapa, 2018).

Little is known about actual metrics to evaluate smart city performance. However, organizations such as the International Organization for Standardization (ISO), British Standards Institutions (BSI), and International Telecommunication Union (ITU) have developed guidelines and key performance indicators (KPIs) to plan and measure smart city performance. The aim of the standards and harmonized metrics is to clarify the complex city processes, urban planning, and needs of multifaceted stakeholder groups. Smart city standards assist cities to compare procurement proposals and reduce barriers to system integration in complex city organization and infrastructures. Further, these standards provide practical step-by-step guides and function as valuable tools for smart city practitioners and stakeholders to transit a city towards becoming a digitized smart city (BSI, ISO, ITU.)

3.4 Stakeholders

Smart cities are described as collaborative innovation ecosystems (Komninos, Pallot, & Schaffers; 2013; Komninos & Tsarchopoulos, 2013) that generate new opportunities for start-ups, multinationals, academia, and cities themselves. Public organizations may collaborate with private companies to develop novel city services that optimize city activities, reduce costs, and save scarce city resources. For enterprises, multifaceted smart city domains provide an environment to experiment and employ new technologies in real-world settings and discover new business and value-creation opportunities in the context of the smart city context (Hämäläinen & Tyrväinen, 2018; Sarma & Sunny, 2017). Thus far, public-industry partnership has dominated smart city initiatives; however, lately, integrating citizens and civil society in the development of a smart city has been emphasized. *Quadruple helix* (public-private-people) collaboration pursued to enhance social inclusion as citizens is seen to lead to the emergence of co-creators and social innovators (Abella et al., 2017; Komninos, Pallot, & Schaffers; 2013; Mayangsari & Novani, 2015; Petersen et al., 2015) in cities. Including citizens in smart city ecosystems is justified by the perception that citizens may own specific knowledge and earn social capital as part of their livelihood (Lea et

al., 2015; Mayangsari & Novani, 2015), which may benefit a community's living conditions. Further, quadruple helix collaborations further enhance technology diffusion and reduce technology resistance in cities.

(h) Stakeholder value

Even though the concept of a smart city has been a popular phenomenon, numerous smart city projects tend to decline once project funding is obtained (Diaconita, Bologa, & Bologa, 2018; Hämäläinen & Tyrväinen, 2016). It must be noted that smart city development is a long-term process, which requires capabilities and resources to generate *added value* for the stakeholders involved in smart city ecosystems (Hämäläinen & Tyrväinen, 2016; Gagliardi et al., 2017). Competences to orchestrate and manage complex technical, human, and business ecosystems are needed to transform a conventional city from the stage of being a smart city pilot to one of mature smart city development. A clear understanding of the actors' roles and responsibilities in the smart city ecosystem has positive influences on ecosystem health and the experienced value of stakeholders (Autio & Thomas, 2014; Korpela et al., 2013; Manikas, 2016). This is also true for smart city ecosystems. The role of an ecosystem orchestrator is to facilitate the ecosystem, its resources, actors, and objectives. A smart city orchestrator ensures a harmonious decision-making process and interaction (Manikas, 2016) so that the objectives of a smart city are achieved and value-added smart city applications and solutions are created in such a city (Abella et al., 2017; Adapa, 2018; Bifulco, Tregua, & Amitrano, 2017; Hämäläinen & Tyrväinen, 2016).

4 Methodology

The foundation for the smart city framework presented in this paper originates from the prior work presented by Hämäläinen and Tyrväinen (2018). The framework was applied to the Helsinki smart city. Data for empirical research was collected by interviewing persons and stakeholders involved in the development of the Helsinki smart city (Table 1). The semi-structured interview protocol was employed in interviews, which provided flexibility and the possibility for a deeper understanding of the development of Helsinki. Interviewee 1 represented the Helsinki environmental protection unit and was in charge of Helsinki city's energy and climate statistical data. Interviewee 2, Deputy CEO, represented the Smart Kalasatama project at Forum Virium Ltd. Interviewees 3 and 4 represented Helsinki Region Infoshare, an organization that releases Helsinki city's open data. Interviewee 5 was a community manager at Smart Kalasatama project, who was responsible of stakeholder relations. Interviewees 6 and 7 represented residents of the Smart Kalasatama district. All interviews were audio recorded and transcribed after the interviews. Additional data was collected by attend-

ing workshops related to smart cities and seminars in Finland, as well as reviewing official Helsinki city reports, documents, and websites. Data was collected during the period May 2017–February 2019.

Data collection			
Interview	**Role**	**Unit**	**Date**
Interviewee #1	Environmental planning	Helsinki city	23.4.2018
Interviewee #2	Deputy CEO	Forum Virium	20.4.2018
Interviewee #3 and 4	Project manager and designer	Open Data Helsinki city	26.3.2018
Interviewee #5	Community manager	Smart Kalasatama	17.5.2017
Interviewee #6	Resident 1	Smart Kalasatama	17.5.2017
Interviewee #7	Resident 2	Smart Kalasatama	17.5.2017
Workshop	**Place**	**Organizer**	**Date**
Open Data Day 2018	Helsinki	Open Data Finland	1.3.2018
City Business - Cities as platforms	Oulu	City of Oulu	6.6.2018
MyData 2018	Helsinki	MyData	29.-31.8.2018
Public material	**Publisher**		
Helsinki city strategy	Helsinki city	https://www.hel.fi	2017 -2021
ICT Policy	Helsinki city	https://www.hel.fi	2015 - 2017
Web page	Helsinki Region Infoshare	https://hri.fi/fi/	
Web page	Forum Virium	https://forumvirium.fi/	
Agile pilot cookbook	Smart Kalasatama		
Web page	Smart Kalasatama	https://fiksukalasatama.fi/en/	
Web page	Stadin ilmasto	https://www.stadinilmasto.fi/	
Web page	6-aika smart city project	https://citybusiness.fi/materiaalit-ja-julkaisut/	

Table 1 Empirical data collection

5 The Helsinki smart city in Finland

The capital of Finland, Helsinki, has over 600,000 inhabitants. The total area of the city is 719 km^2, of which almost 70% is sea (502) and 30% is land (217). The population density in Helsinki is almost 3000 inhabitants per km^2. Smart Kalasatama is a

strategic smart city development district in Helsinki. It is a new residential area, which is expected to provide homes for approximately 25,000 inhabitants by 2040. As a strategic smart city development area, Smart Kalasatama provides facilities for agile smart city pilots with a multi-stakeholder collaboration. The development of Smart Kalasatama is facilitated by Forum Virium Helsinki (FVH) Ltd., an innovation business unit owned by Helsinki city. Further, Helsinki is part of the 'The Six City Strategy' project, which delivers smart city pilot projects in fields such as smart mobility, open data, health, and circular economy in the six largest cities in Finland. 'The Six City Strategy' project was selected as Finland's flagship project for the EU Cohesion Policy's 30th anniversary year. In addition, Helsinki has achieved podium places in several smart city competitions. Helsinki was elected as the number one city at the European Capital of Smart Tourism 2019 competition and the best city for providing digital Mobility-as-a-Service (MaaS) services. (Forum Virium Helsinki, 2018; Helsinki city, 2018; 6Aika project, 2018). In the following account, the smart city framework presented in Figure 1 is applied to the Helsinki smart city.

5.1 Strategy of the Helsinki Smart City

The updated city strategy for the period 2017–2021 proclaims Helsinki to be 'The Most Functional City in the World'. Helsinki commits to take concreate actions to produce high quality city services with strong citizen inclusion. The city aims to be a resident- and user-oriented city, where people may live in a safe and trustworthy environment. Trust, safety, and social coherence are elements that create a competitive edge for Helsinki (Helsinki City Strategy, 2018). However, as expressed by interviewee 2, Helsinki city does not have a specific *smart city or digital strategy*, but the goal of Helsinki is to be the best city in the world to benefit digitalization (Helsinki City Strategy, 2018). Interviewee 2 indicated that in the future, the concept of smart city will be 'a new normal'. The current Helsinki city strategy includes numerous smart city elements and development areas. As an example, Helsinki aims to develop digital solutions that are easy to follow and engage in regardless of who has created the digital services (Helsinki City Strategy, 2018).

(i) Capabilities

Based on the city strategy, Helsinki aims to improve its personnel's capabilities in emerging digital technologies, such as AI and robotics, by providing specific training and education for digital technologies. A specific *Chief Digital Officer* position was established to ensure that digital transformation is actualized in diverse city domains. Helsinki aims to digitalize city services so that they are available around the clock. A new data-based concept of 'smart education' is set to be developed around education services. The smart education concept utilizes data analytics to provide more individ-

ual learning design and experiences. The objective of the smart education concept is to further enhance the learning processes and offer education services, regardless of time and space, for students of all ages in Helsinki (Helsinki City Strategy, 2018).

5.2 Technology: Digital technologies

The ICT and data administration department of Helsinki city operates under its Economic Development and Planning Division. The ICT department is responsible for the steering and development of compatible digital technologies in diverse city domains. The department is also responsible for city-wide enterprise architecture and ICT infrastructure design and implementation. Helsinki targets to provide low-threshold technology innovation and experimentation services and enable digitalized data availability for external stakeholders. The city actively experiments and benefits from data analytics, AI, sensor and IoT technologies in multiple city domains (Helsinki ICT Policy).

(j) Data

The data obtained from Interviewee 1 plays a central role in smart city development. The key issues in this regard are the content of the data, how information is distributed to relevant target groups, and how information is utilized in decision-making processes. As an example, the environmental protection unit of Helsinki initiated multiple projects to release existing data series for public use. Based on statistical environmental data series, a 3D model, Helsinki Energy and Climate Atlas, was created to bring transparency to the energy consumption of city buildings. A visual tool helps a city to assess and analyse energy consumption in diverse city buildings and, thus, react to energy leakages and enhance energy efficiency, particularly in old buildings.

The concept of open data was introduced to the Helsinki administration in the year 2009. Subsequently, a specific organization, Helsinki Region Infoshare, was established to organize and manage open data initiatives in Helsinki and its surrounding cities. In European settings, the Helsinki regional public libraries were the first ones to publish raw data from over 680,000 works for public use in 2010. The Helsinki city strategy states that Helsinki will be a leading city in terms of releasing and utilising public open data. Currently, Helsinki and its regional cities have published almost 650 data sets and opened almost 120 interfaces for external stakeholders. Helsinki Regional Transportation, Service Map Application Programming Interfaces (APIs) and geographical data—such as maps and postcodes—have been the most popular interfaces and data sets that are applied by open data users. Although Helsinki city has increasingly begun to release public data sets, not all of its city organizations publish

their data for public use. Interviewees 3 and 4 mentioned that city organizations such as social and health services have legitimate grounds that prevent extensive data sharing with the public. For example, a recently published General Data Protection Regulation (GDPR) in Europe tightens the protection of personal data and limits city organizations to collect, share, and use data that contains personal information such as name, address, and social security number. Other factors such as prejudice, deficiency in capabilities, and lack of time and money were mentioned as reasons that prevent other city organizations to implement open data initiatives. However, Interviewees 3 and 4 also mentioned that strategic focus on open data, successful open data projects, and practices and improved ICT solutions have lowered the prejudices and resistance towards open data. Further, the interviewees indicated that the open data concept must be promoted more actively in diverse city domains and that, currently, sufficient resources are not reserved for these purposes.

(k) Technology experimentations

Helsinki city has established an independent company, Forum Virium Helsinki (FVH) Ltd., for developing new digital innovations and city services in collaboration with private companies, other public organizations, and citizens. City-level strategy and FVH emphasize that Helsinki will be an attractive and leading city for agile smart city technology experimentations, thereby stimulating new business activities in the city. A user-driven approach and agile smart city development are FVH's key drivers. Currently, FVH runs digital technology development and experimentations at Smart Kalasatama as well as at other city districts. During the years 2015–2018, FVH has organized 21 agile smart city technology and service experimentations in Kalasatama. Each pilot lasts six months and pilots are run twice a year. FVH procures pilots with a maximum of 8000 euros. The smart city pilot themes have included, for example, smart-mobility services, effective waste management, food waste reduction, and co-creation of local well-being services. FVH's slogan 'fail fast, learn fast' indicates that stakeholders may test smart city solutions in a areal-world city environment with actual users and simultaneously learn if the smart city solution is viable on a larger scale. Smart Kalasatama agile pilots and technology experimentations have raised interest not only in Helsinki but also in other cities in Finland and Europe. Due to high interest displayed towards agile urban development through technology pilots, a cookbook for Agile Piloting was published in the spring of 2018. The Smart Kalasatama cookbook presents the best practices and lessons learned in Kalasatama smart city pilots. Smart Kalasatama emphasizes maximizing learning and integrating diverse stakeholder groups for user-driven smart city development. (Smart Kalasatama.)

(l) Vertical and horizontal scope

Numerous smart city initiatives and experimentations in Helsinki have concerned mobility, environment, and circular economy development. Helsinki has actively developed functional smart traffic systems to reduce emissions and created advantages for modern technologies and sharing economy principles to modernize urban mobility. (Helsinki city strategy.) Mobility-as-a-service is one of the most extensive efforts that have taken place in Helsinki. As a result of mobility and transportation development, new data-driven innovations and services have emerged. An application called 'Whim' aggregates both public and private transportation services in one place, thereby offering users services such as city bikes, taxi, and private car services at an affordable monthly fee. Whim liberates citizens from car ownership, thereby making urban life more flexible and resource-efficient. Another digital service created by Helsinki city is a digital platform called 'Service Map'. 'Service Map' encompasses almost all city services, thereby making it easier for citizens to browse and search city services through one digital platform. Both Whim and Service Map platforms utilize open data sets published on HRI's open data platform. Helsinki's ICT department develops ICT policies that support the implementation of the city strategy. Further, the ICT department harmonizes ICT systems so that city services are compatible and digital data content and interfaces are easily available for city stakeholders. The city actively enhances the emergence of open ICT ecosystems by offering fair and equal opportunities for third parties to develop new digital city services (Interviewees 3 and 4, 2018; Open Data Day, 2018.)

(m) Security and privacy

Helsinki's ICT policy states that new ICT training programs must focus on smart city development by enhancing security and privacy issues in diverse city domains. Interviewee 1 expressed that privacy and data protection issues may prevent extensive use of data in certain cases. Interviewees 3 and 4 indicated that city lawyers are used to consulting diverse city organizations, for example, with data privacy matters. Thus, Helsinki considers security and privacy issues and renews ICT procurement practices in this field.

5.3 Governance

In terms of smart city governance, Interviewee 2 expressed that the notion of a smart city is currently related to the manner in which cities govern their ICT systems and data and how they integrate new digital technologies into city infrastructure. Another strong trend in the smart city development discourse is a participatory and citizen-driven/centric approach. In the case of Helsinki, an organization that governs the

development of the Helsinki smart city and related initiatives does not seem to exist; however, instead, the development of the smart city is decentralized. Numerous Helsinki smart city initiatives run by FVH are project-based and funded by the EU. Interviewee 2 indicated that due to intensive competition for funding, the projects are rather arbitrary. Interviewee 2 summarized the development of the Helsinki smart city in the following manner:

'We have put huge efforts for developing agile pilots and creating an experimentation culture in Helsinki. It has been an excellent way to motivate and mobilize the entire urban society to develop concrete smart city solutions, for example, related to mobility and health care. Developing a culture for agile pilots and technology experimentations has activated Helsinki city officials, citizens, and start-ups to develop and figure out how to benefit from novel digital technologies and what the future of the city will look like. It is definitely worth it to continue agile pilot and experimentation activities and consider how to extend and draw agile pilots on city-level strategic projects and procurements'.

Interviewee 2 continues and envisions that,

'when technologies evolve, we have artificial intelligence, data, robotics and so on, the city infrastructures and governance must not only adapt to changes, but a city must be governed and managed in another way. The smart city will be the new normal'.

Interviewee 2 also emphasizes combining top-down and bottom-up urban development. This implies that a city-level strategy is needed to deliver investments for infrastructure development; simultaneously, the strategy must engage all stakeholders from private and public sectors and the civil society to develop urban areas. In a top-down/bottom-up urban development approach, the city opens up its data interfaces and develops ICT systems so that each citizen may participate and use his/her resources to improve the quality of lives of the citizens of the city. In the case of Helsinki, agile pilots and new technology experimentations are the means for the development of a smart city. As the development of a smart city evolves in Helsinki, it could be expected that this development progresses from agile pilots to a more mature smart city governance approach.

(n) Funding and metrics

Interviewee 2 indicated that the work of FVH is project-based work. Smart Kalasatama itself is a city's strategic development project and is, thus, funded by Helsinki. However, the agile smart city pilots and experimentations are funded by diverse EU

funds. In addition, local and national public organizations have participated and invested in the Helsinki smart city pilots. Due to high competition and uncertainty of the smart city project funding, Interviewee 2 pondered that a city-level smart city development might potentially provide a more solid funding base. One example of the smart city organization or initiatives funded by Helsinki city is Helsinki Regional Infoshare (HRI) for open data services. HRI is an organization that receives funding from Helsinki, other regional cities, and public organizations in Finland. In addition, the digital city services that are developed on the basis of open data are funded by Helsinki. None of the international smart city standards are applied in Helsinki. However, metrics to measure smart city agile pilots organized by FVH are determined by funding organizations. Although the precise metrics to measure benefits from open data initiatives are not set and measured, Interviewees 3 and 4 estimated that, for example, open procurement data has resulted in 1–2% savings in city procurement activities.

5.4 Stakeholders

The strategy of creating 'The Most Functional City in the World' implies that a functional city is extended to involve all citizens and stakeholders in Helsinki. Helsinki is a user- and resident-driven city, which benefits from open data to stimulate the emergence of start-ups and high-growth companies, and offers an advantageous environment for agile pilots and experimentations (Helsinki city strategy). The FVH has executed city-level strategy and actively implemented *quadruple helix* smart city collaboration and development in Smart Kalasatama and other areas in Helsinki. The agile pilots applied in Smart Kalasatama integrate the entire urban society: city, citizens, start-ups, civil society, academia, and large companies. The principles of agile pilots and stakeholders involved in technology experimentations are presented in Figure 2.

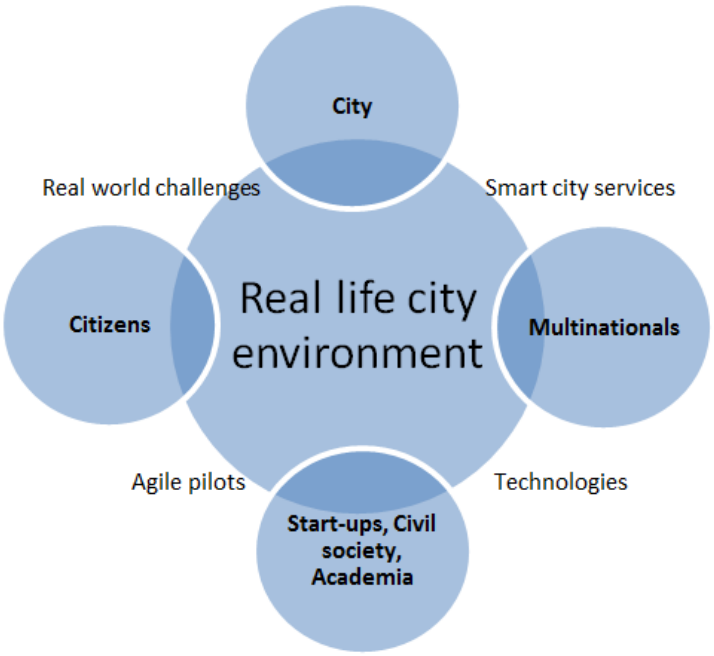

Figure 2 Smart Kalasatama Quadruple Helix (adapted from the Smart Kalasatama presentation)

Another environment created for a *quadruple helix* collaboration in Helsinki is called *Maria 01 area.* Maria 01, a co-working area, is a low threshold meeting place where individuals, third-sector actors, companies, and city officials can collaborate and co-create solutions for citizens and other customers. Maria 01 aims to stimulate individual developers and start-ups to create new digital city services based on open data and accelerate the emergence of new innovations and businesses (Helsinki city strategy).

(o) Stakeholder value

Helsinki has managed to create an attractive smart city experiment and agile piloting culture, which stimulates and integrates diverse stakeholder groups. For Helsinki city, agile pilots have made smart city development more concrete and visible and opened up possibilities for learning about which smart city solutions work and which do not. The 'fail fast, learn fast' approach is well adopted in Smart Kalasatama. Further, agile pilots have stimulated the creation of a smart city ecosystem and trust among the stakeholders of the Helsinki smart city. Interviewee 5 highlighted the FVH's role as a facilitator during agile pilots and emphasized that agile pilots must create value for the stakeholders of a smart city. As a facilitator, the FVH functions as

a hub for different stakeholders, lowering the threshold for communication and access for agile pilots. Further, in a facilitator role, the FVH is able to eliminate, for example, legislative barriers or authorization requests from authorities, which streamline the process of agile pilots. Interviewee 5 emphasized that stakeholders' experience contributes to the success of agile pilots and willingness to participate in pilot activities.

Interviewees 5 and 6 represented Smart Kalasatama residents. Both residents considered agile pilots to be beneficial and had a positive attitude towards technology experimentations. The possibility of influencing and being involved in the Smart Kalasatama development was a major reason for attending agile smart city pilots. Interviewee 6 mentioned that certain pilot solutions improved his quality of life. However, both Interviewees 5 and 6 agreed that they would like to receive information regarding the service after the experimentation period is over. They stated that they would like to know whether a beta version of the service or solution will be provided and improved upon and whether it would be available later on.

Due to lack of time and resources, this research did not include the experienced stakeholder value from developers who conducted the agile pilots. Developer data would have enriched the research in terms of stakeholder value. Similarly, the experienced stakeholder value from Helsinki open data is limited to Interviewees 3 and 4. From their perspective, public city data has increased transparency and is expected to increase civic participation and bottom-up urban development. Other benefits that the city has received from open data are internal savings and resource efficiency, as data is ubiquitously available for all. The third benefit mentioned by these interviewees is the hope that the provision of open data stimulates new business and improves the competitiveness of the companies in Helsinki and Finland. However, clear evidence of new business was not present.

6 Summary

Digital transformation is a multifaceted long-term process that influences an organization's structures, processes, resources, capabilities, and stakeholders. This paper presented a framework for smart city design that was applied to the development of the Helsinki smart city. The smart city design framework considered the Helsinki smart city through four dimensions: *strategy*, *technology*, *governance*, and *stakeholders*— and their sub-dimensions (Fig. 3). Each dimension is scaled from 0 to 3. Value 0 indicates no activities, value 1 indicates moderate performance, value 2 indicates good performance, and value 3 indicates excellent performance.

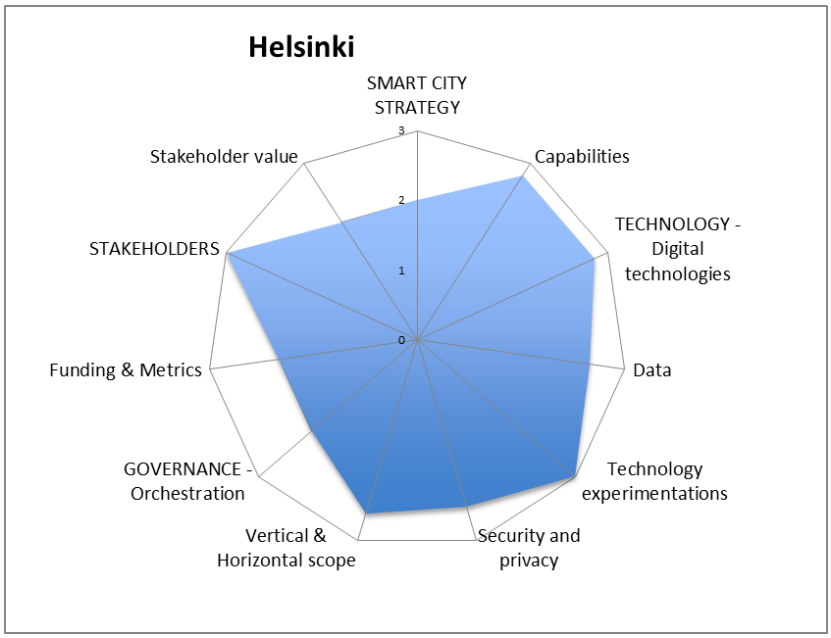

Figure 3 The development of the Helsinki smart city through four dimensions

In the case of Helsinki, specific digital or smart city strategy is missing, but a valid city-wide strategy for the period 2017–2021 supports city development through digital technologies. Interviewee 2 indicated that the smart city will be the new normal, which implies that digitalization and digital technologies are a natural part of urban development. The Helsinki city strategy emphasizes digitalization, user-centric development, civic society engagement, and agile technology pilots. In order to support digital transformation Helsinki has recently hired a Chief Digital Officer to ensure robust digital transformation and smart city delivery in diverse city domains. Helsinki also educates and trains its personnel in modern digital technologies, but not all city divisions have sufficient resources to fully implement digital technologies.

Further, Helsinki aims to develop the entire city as a platform where new and creative city solutions are developed and experimented with. In order to achieve this objective, Helsinki has established a separate innovation unit called the FVH Ltd., for agile digital technology testing and smart city development. The aim of the FVH is to activate digital innovation and organize agile technology experimentations in diverse areas in Helsinki. In addition, Helsinki has managed to create a specific experimentation culture for novel digital technologies like IoT solutions and data usage within diverse city organizations. The city has initiated numerous initiatives to exploit existing data series from different city organizations. Helsinki Region Infoshare (HRI), an open city data platform, is an example of the work Helsinki has committed to in terms

of promoting and using data in the development of a smart city. The HRI platform systematically releases open city data sets and interfaces for public use. In order to avoid emergence of data silos and enhance data horizontality, Helsinki aims to harmonize its ICT infrastructure and eliminate the barriers that prevent cross-border data flows among city organizations. Security and privacy issues are of relevance and, in certain cases, may prevent extensive use and publication of city data.

A major proportion of the development work for the Helsinki smart city is short-term and project-based. The FVH, as a separate innovation unit, orchestrates individual smart city projects and facilitates agile technology pilots in practice. In addition to quadruple helix collaboration, FVH and other Helsinki city organizations develop smart city solutions that are relevant for the city, citizens, and other actors in the city. The development of a smart city in Helsinki is rather scattered, which makes the governance of the smart city slightly confused. A clear connection between short-term agile experimentations and long-term smart city development is difficult to discern. However, smart city initiatives and pilots, particularly in Smart Kalasatama, are considered valuable for city stakeholders, such as residents and city authorities. Smart Kalasatama residents expressed that agile pilots are beneficial, but they would have liked to receive information about the solution after the pilot was completed. Further, due to time limitations, stakeholders that develop smart city solutions were not involved in this research.

Numerous Helsinki smart city initiatives are funded through diverse EU funds, Helsinki city, and private organizations. The metrics to measure the outcomes of smart city initiatives are determined by funding organizations, but no international standards for smart city activities are applied in Helsinki. In addition, empirical data did not reveal information about the metrics used to measure the city-level digital transformation process.

7 Conclusion

Digital transformation is a complex and long-term process, which influences an organization's structures, processes, resources, capabilities, and stakeholders. Digital transformation is all the more embedded in social areas that influence all aspects of human life (Stolterman & Fors, 2004). This paper presented a framework for smart city design. This framework shed light on the elements that are relevant for robust smart city implementation and enhanced effectiveness of smart city governance and quadruple helix collaboration. The framework was applied to the Helsinki smart city and considers smart city initiatives from the four major dimensions of *strategy*, *technology*, *governance*, and *stakeholders*, as well as their sub-dimensions. Helsinki does not have a specific smart city or digital strategy, but the city-level strategy considers digitalization and user-oriented urban development as one of the areas that is accord-

ed priority. In the future, a smart city may be considered the *new normal*, thereby implying that digital technologies and data are embedded in urban development. However, specific smart city or digital strategies might enhance digital transformation and clarify the governance and investment needs for the development of a smart city. In addition, a specific smart city strategy could consider how to integrate agile technology pilots with city-level strategic projects and procurements and, thus, also accelerate the socio-economic aspect of the development of a smart city.

The agile smart city pilots applied in Helsinki have engendered a strong experimentation culture in Helsinki, which has proven to be an efficient means to enhance socio-technical systems and technology acceptance within the city. Moreover, the quadruple helix collaboration is a well-accepted form for agile pilots and smart city implementation in Helsinki. Drawing closer attention to value-creation aspects might improve the satisfaction of stakeholders and, thus, the robustness and duration of smart city initiatives. Applying international smart city standards would improve the analysis and results of smart city implementations.

References

1. Abella, A., Ortiz-De-Urbina-Criado, M., & De-Pablos-Heredero, C. (2017). A model for the analysis of data-driven innovation and value generation in smart cities' ecosystems. *Cities*, *64*, 47-53.
2. Adapa, S. (2018). Indian smart cities and cleaner production initiatives–Integrated framework and recommendations. *Journal of Cleaner Production*, *172*, 3351-3366.
3. Aguilera, U., Peña, O., Belmonte, O., & López-de-Ipiña, D. (2017). Citizen-centric data services for smarter cities. *Future Generation Computer Systems*, *76*, 234-247.
4. Au, C. H., Tan, B., Leong, C., & Ge, C. (2018). Disrupting the Disruptor: The Role of IS in Facilitating Second-Mover Advantage.*Thirty Ninth International Conference on Information Systems, San Francisco,* 2018.
5. Autio, E., & Thomas, L. (2014). Innovation ecosystems. *The Oxford handbook of innovation management*, 204-288.
6. Baccarne, B., Mechant, P., & Schuurman, D. (2014). Empowered cities? An analysis of the structure and generated value of the smart city Ghent. In*Smart City* (pp. 157-182). Springer International Publishing.
7. Ballon, P., Pierson, J., & Delaere, S. (2005). Test and experimentation platforms for broadband innovation: Examining European practice. *Available at SSRN 1331557*.
8. Batty, M., Axhausen, K. W., Giannotti, F., Pozdnoukhov, A., Bazzani, A., Wachowicz, M., ... & Portugali, Y. (2012). Smart cities of the future. *The European Physical Journal Special Topics*, *214*(1), 481-518.
9. Berman, S., & Marshall, A. (2014). The next digital transformation: from an individual-centered to an everyone-to-everyone economy. *Strategy & Leadership*, *42*(5), 9-17
10. Bharadwaj, A., El Sawy, O., Pavlou, P., & Venkatraman, N. (2013). Digital business strategy: toward a next generation of insights.

11. Bifulco, F., Tregua, M., & Amitrano, C. C. (2017). Co-governing smart cities through living labs. Top evidences from EU. *Transylvanian Review of Administrative Sciences*, *13*(50), 21-37.
12. British Standards Institutions. https://www.bsigroup.com/ Ref. 6.11.2018
13. Caragliu, A., Del Bo, C., & Nijkamp, P. (2011). Smart cities in Europe. *Journal of urban technology*, *18*(2), 65-82.
14. Chanias, S., & Hess, T. (2016, June). Understanding Digital Transformation Strategy formation: Insights from Europe's Automotive Industry. In *PACIS* (p. 296).
15. Commission on Global Governance. (1995). Our Global Neighborhood, Oxford: Oxford University Press. Ref 26.4.2017. http://www.gdrc.org/u-gov/global-neighbourhood/chap1.htm
16. Davenport, T. H., & Westerman, G. (2018). Why so many high-profile digital transformations fail. *Harvard Business Review*, *9*.
17. Diaconita, V., Bologa, A. R., & Bologa, R. (2018). Hadoop Oriented Smart Cities Architecture. *Sensors*, *18*(4), 1181.
18. Díaz-Díaz, R., Muñoz, L., & Pérez-González, D. (2017). Business model analysis of public services operating in the smart city ecosystem: The case of SmartSantander. *Future Generation Computer Systems*, *76*, 198-214.
19. Dobbs, R., Smit, S., Remes, J., Manyika, J., Roxburgh, C., & Restrepo, A. (2011). Urban world: Mapping the economic power of cities. *McKinsey Global Institute*.
20. European Commission. (2018). Ref. 06.11.2018. https://ec.europa.eu/info/eu-regional-and-urban-development/topics/cities-and-urban-development/city-initiatives/smart-cities_en.
21. Forum Virium Helsinki. https://forumvirium.fi/. Ref 02/2019.
22. Gagliardi, D., Schina, L., Sarcinella, M. L., Mangialardi, G., Niglia, F., & Corallo, A. (2017). Information and communication technologies and public participation: interactive maps and value added for citizens. *Government Information Quarterly*, *34*(1), 153-166.
23. Gerster, D. (2017). Digital Transformation and IT: Current State of Research. *Twenty First Pacific Asia Conference on Information Systems, Langkawi.*
24. Gimpel, H., Hosseini, S., Huber, R., Probst, L., Röglinger, M., & Faisst, U. (2018). Structuring Digital Transformation: A Framework of Action Fields and its Application at ZEISS. *Journal of Information Technology Theory and Application*, *19*(1), 31-54.
25. Helsinki city. (2018). City strategy. https://www.hel.fi/helsinki/en/administration/strategy/strategy/city-strategy/ and https://www.hel.fi/static/taske/julkaisut/2013/Strategiaohjelma_2013-2016_Kh_250313.pdf. Ref. 28.07.2018.
26. Helsinki ICT Policy. https://www.hel.fi/static/helsinki/julkaisut/tietotekniikkaohjelma.pdf. Ref. 07/2018.
27. Helsinki Region Infoshare. https://hri.fi/fi/.
28. Henriette, E., Feki, M., & Boughzala, I. (2016, September). Digital Transformation Challenges. In *MCIS* (p. 33).
29. Hernandez, J. F., Larios, V. M., Avalos, M., & Silva-Lepe, I. (2016). INFRASTRUCTURE CONSOLIDATION FOR INTERCONNECTED SERVICES IN A SMART CITY USING CLOUD ENVIRONMENT. *International Journal of Computer Networks & Communications (IJNC)*, *8*(1).
30. Hess, T., Matt, C., Benlian, A., & Wiesböck, F. (2016). Options for Formulating a Digital Transformation Strategy. *MIS Quarterly Executive*, *15*(2).
31. Hamalainen, M., & Tyrvainen, P. (2016, September). A framework for iot service experiment platforms in smart-city environments. In *Smart Cities Conference (ISC2), 2016 IEEE International* (pp. 1-8). IEEE.

32. Hämäläinen, M. & Tyrväinen, P. (2018) Improving Smart City Design: A Conceptual Model for Governing Complex Smart City Ecosystems. In Bled *eConference*. 2018.
33. IRP (2018). The Weight of Cities. Resource Requirements of Future Urbanization. Swilling, M., Hajer, M., Baynes, T.,…Tabory, S. A Report by International Resource Panel. United Nations Environment Programme, Nairobi, Kenya.
34. ISO (2015). https://www.iso.org/news/2015/10/Ref2001.html. Ref. 06.11.2018
35. ITU-T (2015). https://www.itu.int/en/ITU-T/ssc/Pages/info-ssc.aspx. Ref. 06.11.2018
36. Khan, M., Babar, M., Ahmed, S. H., Shah, S. C., & Han, K. (2017). Smart city designing and planning based on big data analytics. *Sustainable Cities and Society*, *35*, 271-279.
37. Komninos, N. (2011). Intelligent cities: variable geometries of spatial intelligence. *Intelligent Buildings International*, *3*(3), 172-188.
38. Komninos, N., Pallot, M., & Schaffers, H. (2013). Special issue on smart cities and the future internet in Europe. *Journal of the Knowledge Economy*, *4*(2), 119-134.
39. Komninos, N., & Tsarchopoulos, P. (2013). Toward intelligent Thessaloniki: From an agglomeration of apps to smart districts. *Journal of the Knowledge Economy*, *4*(2), 149-168.
40. Korpela, K., Ritala, P., Vilko, J., & Hallikas, J. (2013). A management and orchestration model for integrating Digital Business Ecosystems. *International Journal of Integrated Supply Management*, *8*(1/2/3), 24-51.
41. Lea, R., Blackstock, M., Giang, N., & Vogt, D. (2015). Smart cities: Engaging users and developers to foster innovation ecosystems. *Proceedings of the 2015 ACM* International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2015 ACM International Symposium on Wearable Computers, 1535-1542.
42. Legner, C., Eymann, T., Hess, T., Matt, C., Böhmann, T., Drews, P., ... & Ahlemann, F. (2017). Digitalization: opportunity and challenge for the business and information systems engineering community. *Business & information systems engineering*, *59*(4), 301-308.
43. Li, F., Nucciarelli, A., Roden, S., & Graham, G. (2016). How smart cities transform operations models: a new research agenda for operations management in the digital economy. *Production Planning & Control*, *27*(6), 514-528.
44. Lu, D., Tian, Y., Liu, V. Y., & Zhang, Y. (2015). The performance of the smart cities in China—A comparative study by means of self-organizing maps and social networks analysis. *Sustainability*, *7*(6), 7604-7621.
45. Manikas, K. (2016). Revisiting software ecosystems research: A longitudinal literature study. *Journal of Systems and Software*, *117*, 84-103.
46. Matt, C., Hess, T., & Benlian, A. (2015). Digital transformation strategies. *Business & Information Systems Engineering*, *57*(5), 339-343.
47. Mayangsari, L., & Novani, S. (2015). Multi-stakeholder co-creation analysis in smart city management: an experience from Bandung, Indonesia. *Procedia Manufacturing*, *4*, 315-321.
48. Mithas, S., Tafti, A., & Mitchell, W. (2013). How a Firm's Competitive Environment and Digital Strategic Posture Influence Digital Business Strategy. *Mis Quarterly*, *37*(2).
49. Morakanyane, R., Grace, A. A., & O'Reilly, P. (2017). Conceptualizing Digital Transformation in Business Organizations: A Systematic Review of Literature. In *Bled eConference* (p. 21).
50. Perez, I., Poncela, J., Moreno-Roldan, J. M., & Memon, M. S. (2015). IntelCity, Multiplatform Development of Information Access Platform for Smart Cities. *Wireless Personal Communications*, *85*(2), 463-481.
51. Petersen, S. A., Concilio. G., & Oliveira, M. (2015). Smart Neighbourhood Learning-the case of MyNeighbourhood. *IxD&A*, *27*, 66-78

52. Petrolo, R., Loscri, V., & Mitton, N. (2017). Towards a smart city based on cloud of things, a survey on the smart city vision and paradigms. *Transactions on Emerging Telecommunications Technologies*, *28*(1), e2931.
53. Prince, K. A. (2017). Industrie 4.0 and Leadership. ICEB 2017 Proceedings. 23.
54. Rathore, M. M., Son, H., Ahmad, A., & Paul, A. (2018). Real-time video processing for traffic control in smart city using Hadoop ecosystem with GPUs. *Soft Computing*, *22*(5), 1533-1544.
55. Rauch, M., Wenzel, M., & Wagner, H. T. (2016). The Digital Disruption of Strategic Paths: An Experimental Study.
56. Recupero, D. R., Castronovo, M., Consoli, S., Costanzo, T., Gangemi, A., Grasso, L., ... & Rapisarda, S. D. (2016). An innovative, open, interoperable citizen engagement cloud platform for smart government and users' interaction. *Journal of the Knowledge Economy*, *7*(2), 388-412.
57. Ross, J. W., Sebastian, I., Beath, C., Mocker, M., Moloney, K., & Fonstad, N. (2016). Designing and executing digital strategies. *ICIS, 2016.*
58. Ross, J. W., Beath, C. M., & Sebastian, I. M. (2017). How to develop a great digital strategy. *MIT Sloan Management Review*, *58*(2), 7.
59. Ruhlandt, R. W. S. (2018). The governance of smart cities: A systematic literature review. *Cities*, *81*, 1-23.
60. Sahu, N., Deng, H., & Mollah, A. (2018). Investigating The Critical Success Factors Of Digital Transformation For Improving Customer Experience. *CONF-IRM 2018 Proceedings. 18.*
61. Sarma, S., & Sunny, S. A. (2017). Civic entrepreneurial ecosystems: Smart city emergence in Kansas City. *Business Horizons*, *60*(6), 843-853.
62. Schaffers, H., Sällström, A., Pallot, M., Hernández-Muñoz, J. M., Santoro, R., & Trousse, B. (2011, June). Integrating Living Labs with Future Internet experimental platforms for co-creating services within Smart Cities. In *2011 17th International Conference on Concurrent Enterprising* (pp. 1-11). IEEE.
63. Schleicher, J. M., Vögler, M., Inzinger, C., & Dustdar, S. (2017). Modeling and management of usage-aware distributed datasets for global Smart City Application Ecosystems. *PeerJ Computer Science*, *3*, e115.
64. Scuotto, V., Ferraris, A., & Bresciani, S. (2016). Internet of Things: Applications and challenges in smart cities: a case study of IBM smart city projects. *Business Process Management Journal*, *22*(2), 357-367.
65. Sebastian, I. M., Ross, J. W., Beath, C., Mocker, M., Moloney, K. G., & Fonstad, N. O. (2017). How Big Old Companies Navigate Digital Transformation. *MIS Quarterly Executive*.
66. Singh, A., & Hess, T. (2017). How Chief Digital Officers Promote the Digital Transformation of their Companies. *MIS Quarterly Executive*, *16*(1).
67. Six City. https://6aika.fi/. Ref. 02/2019.
68. Smart Kalasatama. https://fiksukalasatama.fi/.
69. Srivastava, S., Bisht, A., & Narayan, N. (2017, January). Safety and security in smart cities using artificial intelligence—A review. In *Cloud Computing, Data Science & Engineering-Confluence, 2017 7th International Conference on* (pp. 130-133). IEEE.
70. Stolterman, E., & Fors, A. C. (2004). Information technology and the good life. In *Information systems research* (pp. 687-692). Springer, Boston, MA.
71. Teubner, R. A. (2013). Information systems strategy. *Business & Information Systems Engineering*, *5*(4), 243-257.

72. Tillie, N., & van der Heijden, R. (2016). Advancing urban ecosystem governance in Rotterdam: From experimenting and evidence gathering to new ways for integrated planning. *Environmental Science & Policy*, *62*, 139-144.
73. Tilson, D., Lyytinen, K., & Sørensen, C. (2010). Research commentary—Digital infrastructures: The missing IS research agenda. *Information systems research*, *21*(4), 748-759.
74. UNEP. (2013). *City-Level Decoupling: Urban resource flows and the governance of infrastructure transitions*. *Summary for policy makers*. Chapter: Introduction and overview. Swilling, M. Robinson, B., Marvin, S. & Hodson, M.
75. Veeckman, C., & van der Graaf, S. (2015). The city as living laboratory: Empowering citizens with the citadel toolkit. *Technology Innovation Management Review*, *5*(3).
76. Vilajosana, I., Llosa, J., Martinez, B., Domingo-Prieto, M., Angles, A., & Vilajosana, X. (2013). Bootstrapping smart cities through a self-sustainable model based on big data flows. *IEEE Communications magazine*, *51*(6), 128-134.
77. Von Solms, R., & Van Niekerk, J. (2013). From information security to cyber security. *computers & security*, *38*, 97-102.
78. Weill, P., & Woerner, S. L. (2015). Thriving in an increasingly digital ecosystem. *MIT Sloan Management Review*, *56*(4), 27.
79. Yovanof, G. S., & Hazapis, G. N. (2009). An architectural framework and enabling wireless technologies for digital cities & intelligent urban environments. *Wireless personal communications*, *49*(3), 445-463.