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Improving Smart City Design: A Conceptual Model for Governing Complex Smart City Ecosystems

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Abstract Smart city concept is a viable nominee to solve the dilemmas urbanization creates globally. By means of digital technologies like Internet-of-Things, artificial intelligence and data analytics cities aim to optimize city performances like mobility, environment, security, health care and social services. Furthermore, cities actively endorse usage of digital technologies to foster digitalization and new business innovation to nurture local economy and social well-being. Smart city market is growing, but simultaneously fragmented smart city markets and initiatives face challenges with governance, ecosystem orchestration and continuity. Transformation to smart city is a complex long-term process, which requires collaboration with heterogeneous stakeholder groups and capabilities to evaluate wide spectrum of new digital technologies and their fitness to diverse city functions and processes. This sets high demands for the smart city governance and management. A smart city conceptual model (SCCM) presented in this paper aims to assist cities with this endeavor. SCCM observes complex smart cities from organizational and technical perspectives providing practical instrument for smart city stakeholders to lead city towards data and digital technology assisted smart city. SCCM considers four primary dimensions, strategy, technology, governance and stakeholders. Each primary dimension is complemented with sub-elements, which all together form meaningful interrelations and provides comprehensive and systematic approach for the smart city design, development and implementation.

Keywords: • Smart city • Strategy • Governance • Stakeholders • Technology • Ecosystem • Digital technologies •

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1 Introduction

The smart city concept attracts city governments, industries and academia globally. In the area of EU alone, over 1300 smart city related proposals, commitment and project exist. European cities invest on information and digital technologies to renew power grids, buildings, public transportation and waste management systems. (European innovation partnership on smart cities and communities.) By investing on modern smart city technologies cities aim to enhance city security, optimize city processes and usage of scarce resources and improve data driven city governance. Cities aim also by means of digital technologies to foster new knowledge creation and innovation and stimulate local businesses and collaboration. (Baccarne, Mechant & Schuurman, 2014; Batty et al., 2012; Caragliu, Del Bo & Nijkamp, 2011; Gabrys, 2014; Li, Nucciarelli, Roden & Graham, 2016; Zanella et al., 2014.)

Even though smart city has been a trendy phenomenon and smart city markets are growing it is worth bearing in mind that each city should focus on developing the smart city from its own particular needs and perspectives. As cities are constantly evolving systems and vulnerable to external uncertainties (Jabareen, 2013) smart city initiatives should be considered as long-term development process, which impacts for instance city strategy, resources, capabilities and stakeholder relations. Creating a specific *smart city strategy* is proposed to consider and analyze city´s macro environment, but also evaluate feasibility of the new digital technologies in diverse city domains and recognize resources and capabilities needed for the smart city transformation. The specific smart city strategy also addresses risks and funding needs for smart city initiatives.

Objective of this paper is to present smart city conceptual model (SCCM) that assists cities and their stakeholders to carry out robust smart city initiatives and enhance sustainable smart city ecosystem design and development. Foundation for SCCM is derived from the systematic literature review of the smart city ecosystems and value networks. SCCM originates from a perception that design and management of the complex smart city is not a trivial task and many smart city initiatives have failed due to weak smart city governance, ecosystem orchestration and insufficient digital technology knowledge and capabilities. SCCM aims thus to clarify complex smart city governance, ownership, orchestration and decision making procedures and advance technological compatibility and correct skills and resource allocation in cities Furthermore, SCCM aims to provide tools to accelerate competitiveness, transparency and economic growth in cities.

This paper first discusses the methodological principles and secondly presents the conceptual foundations for the smart city conceptual model. Conclusion section summarizes and finalizes the paper.

2 Methodology

Smart city is a complex phenomenon, which interest diverse research disciplines like social and environmental sciences, information systems, computer and engineering, urban development and business & economics. Purpose of this paper is to build a smart city conceptual model, which derives its foundations from the literature of the smart city ecosystems and value networks in diverse research fields. Jabareen (2009) suggests that qualitative methods are adequate and useful for building conceptual frameworks from the multidisciplinary literature. Grounded theory as a research method offers a procedure for conceptual framework analysis and building conceptual frameworks (Jabareen, 2009). As an inductive theory the grounded theory allows the salient concepts to emerge from the literature (Wolfswinkel, Furtmueller & Wilderom, 2013) and identify the major concepts relevant for the study phenomenon (Jabareen, 2009). Due to the multidisciplinary nature of the smart city phenomenon, the principles from the "Grounded-Theory Literature-Review Method" by Wolfswinkel et al. (2013) and the conceptual framework analysis by Jabareen (2009) were utilized when conducting the literature review. The literature review addressed the search terms "smart city", "intelligent city" or "digital city" ecosystems and "smart city", "intelligent city" or "digital city" value networks. The search terms were applied to Scopus, Web-of-Science, SAGE Journal Online and AISeL databases. (Table 1.)

Table 4: Search terms and databases

Search terms	Scopus Elsevier API	Web-of-Science (WoS)	SAGE Journals Online	AISeL	Total
"smart city" + ecosystem	41	21	29	8	99
"digital city" + ecosystem	0	1	6	0	7
"intelligent city" + ecosystem	4	3	3	0	10
"smart city" + value network	25	12	2	11	50
"intelligent city" + value network	1	0	0	0	1
"digital city" + value network	3	3	0	2	8
Total	**74**	**40**	**40**	**21**	**175**

Search terms covered articles from social and environmental sciences, information systems, computer and engineering, urban development and business & economics disciplines. Alltogether 175 articles were found, but after removing dublicates 126 journal articles were left. Document titles and abstracts were reviewed and 44 papers were selected for closer review. Based on the key terms that emerged from the literature concepts of strategy, technology, governance and stakeholders formed the parent dimensions for the smart city conceptual model. The sub-concepts were derived from the literature review complemented with the relevant articles from the literature of strategy and organization management, software ecosystems and from the literature of the smart city technology test and experimentation platforms.

3 Conceptual Foundations

Objectives of the robust smart city is to accelerate and reduce costs of the city services and enhance the return on investments (Vilajosana et al., 2013), accelerate economic growth and competitiveness and transparency (Perez, Poncela, Moreno-Roldan & Memon, 2015; Yovanof & Hazapis, 2009). An explicit smart city design clarifies complex smart city governance, stakeholder relationships, orchestration and decision making procedures (Scuotto et al., 2016; Vilajosana et al., 2013) and advances technological compatibility and correct resource allocation in cities (Carvalho, 2015; Scuotto et al., 2016; Vilajosana et al., 2013; Veeckman & van der Graaf, 2015), but above all smart city initiatives should aim to improve the quality of citizens lives. The following chapters present the conceptual foundations for the SCCM, which consists of *strategy, technology, governance,* and *stakeholder* dimensions (Fig 1). Strategy dimension considers aspects of smart city vision and strategy, capabilities and digital strategy. Technology dimension discusses about digital technologies, architecture design, technology experimentation and security and privacy issues in smart city. Vertical and horizontal scopes conclude technology dimension. Governance section describes orchestration of the smart city stakeholders and ecosystems and considers funding and risk management elements. Final, the fourth stakeholder dimension elaborates quadruple helix and stakeholder value.

3.1 Strategy

Strategy is defined as an analytical process of intentional action plans and stream of decisions (Minzberg, 1978) to achieve the long-term goals under certain conditions (Mintzberg & Waters, 1985). Strategy is also considered as a cohesive response to diagnosed challenges (Rumelt, 2009) identified in the operational environment. Strategy is a deliberate and inclusive plan of action to commit and dedicate the whole organization to common goals. Strategy identifies the use of resources, predicts and evaluates the risks and indicates willingness of action to accomplish the goals. (Henderson, 1989.) Strategy dimension clarifies smart city vision and strategy, digital strategy and enhance to figure out required capabilities.

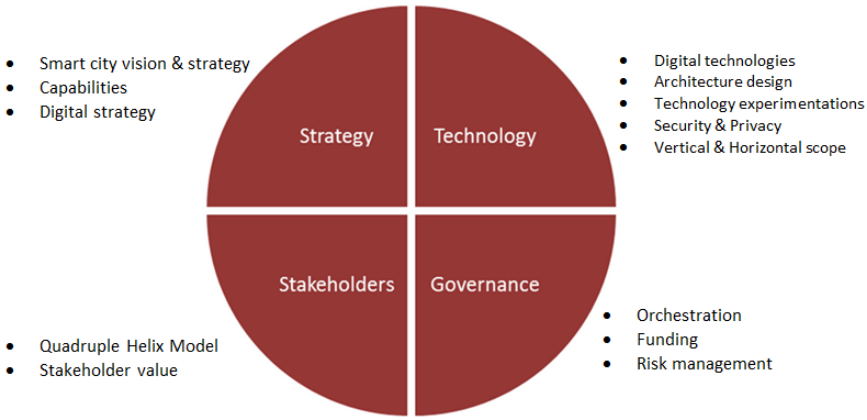

Figure 6: A conceptual model for the smart city design

3.1.1 Smart city vision, strategy, capabilities and digital strategy

Smart city vision´s aim is to express the idea or image of a desirable future (Nanus, 1992) the city is seeking from the smart city initiatives. Vision is characterized as consistent, vivid and dynamic narrative that creates shared meaning of the future clarifying organization´s ambitions and ideology (Collins & Porras; 2005; Levin, 2000). Smart city vision thus acts as a means of communications and is a catalyst for inspiration during the turbulent times and change (Levin, 2000; Nanus, 1992).

Transforming city towards smart city is a long-term journey that requires changes in the city strategy and resources allocation. A specific *smart city strategy* recognizes the changes in political and social conditions, but further identifies the changes that occur in technologies, legislation and economy. The smart city strategy sets goals and considers resources and capabilities required for successful smart city implementation. Smart city capabilities refer to city´s ability to create technical, management and governance skills and knowledge to design and orchestrate innovative and sustainable smart city initiatives that creates value for its stakeholders (Baccarne et al., 2014; Komninos, 2011; Scuotto et al., 2016; Tillie & van der Heijden, 2016). In broader perspective the smart city strategy also considers the impacts of climate change and global political situations on cities´ circumstances.

Ongoing decade has been the rise of new digital technologies. Digital technologies are perceived as a combination of heterogeneous information, cloud computing, communication and connected devices (Bharadwaj, El Sawy, Pavlou & Venkatraman; 2013) complemented with technologies like social media, mobile, big data and data analytics (Ross et al., 2016), artificial intelligence and blockchain technologies. Digital technologies are applied in diverse parts of organization infrastructures. Business units, capabilities, processes and services are interconnected with digital technology solutions

(Bharadwaj et al., 2013). IS literature discuss about combining the strategy and business strategy and calls the fusion as *a digital business strategy (*Bharadwaj et al., 2013; Mithas, Tafti & Mitchell, 2013; Ross et al., 2016). The digital business strategy is defined as organizational or business strategy (Bharadwaj et al., 2013; Ross et al., 2016), which consists of complex and interrelated elements (Mithas et al., 2013) like digital resources and capabilities that create and deliver differential value for the organization operating under constantly changing environment (Bharadwaj et al., 2013; Ross et al., 2016). The digital business strategy thus considers how IS and business strategies jointly not separately reacts to changes in operational environment and create value for the organization and its stakeholders.

In the smart city context digital strategy should support and be aligned with smart city strategy. Smart city strategy envisions the future state of the city by means of digital technologies and considers how complex digital technologies are integrated to the city´s infrastructure to enhance the city processes and functions, service design and capability creation. The smart city strategy acknowledges the common goals and value creation possibilities to citizens and stakeholders in public and private sectors by means of digital technologies.

3.2 Technology

Technology is information, skills and processes to accomplish tasks or artifacts. From sociotechnical perspective technology covers all the elements needed for the output; people, machines, systems and methods, processes, and economical and physical environments. (Kline, 1985; Banta, 2009.) Technology dimension discusses about digital technologies, architecture design, technology experimentations, security and privacy element and vertical and horizontal scope.

3.2.1 Digital technologies and architecture design

Digital technologies like Internet-of-Things (IoT), artificial intelligence (AI), blockchain, big data and data analytics are rapidly escalating and influencing multiple industries and cities. Heterogeneous IoT technologies are widely used in diverse smart city domains to monitor city activities like traffic, parking places and air quality. The data generated and analyzed from IoT network enable more precise data of the city status providing fuel for more accurate decision making. (Sanchez et al., 2014.) AI and blockchain are technologies that are entering into smart city initiatives. AI mimics natural intelligence and cognitive abilities and utilizes technologies like face recognition, machine learning and natural language analysis. AI is utilized e.g. in analyzing health data to optimize public healthcare services and activities (Jiang et al., 2017). Blockchain in turn is a decentralized network, where data is transparent, immutable and transactions are verified. Blockchain technologies are experimented in the areas where control over the personal data and privacy are critical. (Pazaitis, Filippi & Kostakis, 2017; Zyskind & Nathan, 2015.) Digital identities are example of entities, which contain sensitive information like social security numbers, passwords and usernames. In smart city context blockchain

based digital identities improves data transparency and individual´s rights for his/her personal data and reduce risks for data breaches. Smart cities globally are discovering use cases to test and experiment new technologies in diverse city domains.

Foundation for *enterprise architecture* concept originates from the need to combine complex business and information systems (IS) (Zachman, 1987). Enterprise architecture is used as a blueprint (Simon, Fischbach & Schoder, 2013) to describe the components, relationships and interactions of the business processes and information systems (Aier, Kurpjuweit, Saat & Winter, 2009; Ross, Weill & Robertson, 2006; Buckl et al., 2010) and to support orchestration and alignment of the business and IS in the organization (Aier et al., 2009; Müller & Reinert, 2014). Enterprise architecture is like a shared language that clarifies and enhances the communication between organization´s internal and external stakeholders (Aier et al., 2009; Buckl et al., 2010).

In the smart city context architecture design is an instrument to categorize complex city organization into simple, descriptive and well-defined parts (Müller & Reinert, 2014; Zachman International). Smart city architecture design **enhances interoperability and integration of the complex technical components to smart city infrastructure and supports communication and requirements management among stakeholders.** Smart city architecture design provides long-term views on city´s systems, processes, capabilities and digital technologies and **increases smart city implementation success, communication and value creation among the stakeholders.** (Aier et al., 2009; Buckl et al., 2010; Ross et al., 2006).

3.2.2 Technology experimentations in smart cities

Technology test and experimentation platforms (TEP) like testbeds, living labs and prototyping platforms provide facilities to test and experiment new ICT and digital solutions with real users before final release (Ballon, Pierson & Delaere; 2005). For an experimenting organization technology tests and experiments provide facilities to develop technology solutions iteratively and evaluate solution´s feasibility and usability in real-world with real users. Additionally TEPs provide more accurate test results and reduces costs of an evaluation cycle and improves technology innovation and user adoption. (Hämäläinen & Tyrväinen, 2016; Sanchez et al., 2014.)

Cities provide multidimensional environment for developing and testing diverse combination of digital technologies. In the smart city settings living labs have been popular environments to test new technologies and solutions. Elements like involvement of the city and citizens, heterogeneous digital technologies, openness, real-world experiments and scalability are fundamental to technology experimentations´ success in the smart cities. Opening smart city TEPs to external stakeholders´ use the city enhance heterogeneous digital technologies´ reliability and interoperability in the real-world city domains. Simultaneously access to the smart city assets like TEP facilities, information, application development interfaces, technologies and user communities are available to

the smart city stakeholders. (Hämäläinen & Tyrväinen, 2016; Olivares, Royo & Ortiz, 2013; Sanchez et al., 2014; Schaffers et al., 2011; Yokoyama, 2015.)

Real-world smart city use cases benefit all the stakeholders in the smart city ecosystem. There for real-world smart city technology experimentations are emphasized when implementing new technologies in the cities.

3.2.3 Security and privacy

Term cyber security is defined as "the protection of cyberspace itself, the electronic information, the 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). Along with the protection of the ICT infrastructure and information, the cyber security concerns the protection of the individuals and the infrastructure of the society and the whole nation (Von Solms & Van Niekerk, 2013). *Privacy* refers to individual´s rights to his/her personal data. Oliveira & Zaïane (2004) determines the privacy as "users´ rights to conceal their personal information and have some degree of control over the user of any personal information disclosed to others".

Digital technologies are integral part of the smart city initiatives and new digital technologies are widely applied in multiple city domains. However, the more digital technologies are applied in the smart city infrastructure, the greater the potential for vulnerabilities and data breaches. Actualized cyber-attacks may in the worst cases paralyze city´s power grids and water supplies or disable the critical telecommunication connections. Unprotected digital smart city solutions may also lead to misuse of private data or data breaches. Smart cities are forced to consider carefully cyber security and issues like ownership and access to the city´s digital services, platforms and data (Carvalho, 2015; Merlino et al., 2015; Mital, Pani, Damodaran & Ramesh; 2015; Lengyel et al., 2015) to guarantee the safety and security of the smart city.

3.2.4 Vertical and horizontal scope

Many smart-city initiatives have been created around a certain *vertical industry* or an industry emphasizing the goals of a single vertical theme, such as energy efficiency, traffic or health care. The vertical approach in smart city initiatives influences the choice of employed technologies and standards that will best support the needs and requirements of a chosen industry. (Hämäläinen & Tyrväinen, 2016.) Focusing only on particular vertical restricted data silos may emerge. This may prevent more extensive technology and data adoption and exploitation in smart cities. *Horizontality* in smart city context describes a wider set of IoT devices and other wireless sensors, applications and services combining data from multiple city domains and industries to service developers. The horizontal approach contributes broader set of data and expands the possibilities to create new services based on integrated vertical data.

3.3 Governance

Governance is defined as "the sum of the many ways individuals and institutions, public and private, manage their common affairs. It is the continuing process through which conflicting or diverse interests may be accommodated and co-operative action may be taken". (Commission on Global Governance, 1995.) Governance dimension consists of ecosystem orchestration, funding and risk management.

3.3.1 Smart city ecosystems and orchestration

Ecosystem *management and orchestration* enhances the evolution and sustainability of the ecosystem and increases the value for ecosystem actors (Korpela, Ritala, Vilko & Hallikas, 2013; Manikas, Wnuk & Shollo, 2015). The orchestrator´s role is to form common vision for the ecosystem and facilitate ecosystem emergence (Korpela et al., 2013) and sustainability. The orchestrator manages and leads the actors to desired common direction (Korpela et al., 2013) and ensures ecosystem decision making process (Manikas, 2016). Furthermore, the orchestrator co-ordinates the critical resources required for the ecosystem evolvement and enhance the creation of trust and value among the ecosystem actors (Autio & Thomas, 2014).

Smart city is determined as an organic, collective and collaborative ecosystem (Baccarne et al., 2014; Komninos, 2011), which co-create sustainable innovations and engender innovative entrepreneurial, social and innovation ecosystems to improve the economy, human capital and quality of life in a city (Baccarne et al., 2014; Komninos, 2011; Roth, Kaivo-Oja & Hirschmann, 2014; Schaffers, Ratti & Komninos, 2012). In the smart cities multiple ecosystems and numerous stakeholder relationships exist. Smart city ecosystem orchestration and clear role management improve communication and value creation among stakeholders and thus enhance the success of smart city initiatives.

3.3.2 Funding and risk management

Funding and financial resources are critical for the smart city initiatives. Both public and private investment organizations fund the smart city projects of various scales. Funding programs are available for infrastructure development, capacity building, and research and innovation activities. Little is known about the smart cities´ return-on-investments (ROI) or smart city investments´ impacts on socio-economic issues like employment and new business model innovations. Standards and metrics to evaluate the success of the smart city strategy and investments are thus emphasized.

Smart cities generate opportunities, but simultaneously also risks. In complex and decentralized organizations like cities demand for coordinated risk management policy exist (Oulasvirta & Anttiroiko, 2017). Risk management should have a strategic focus (Duckert, 2010) and be aligned with organization strategy. In the smart cities risks concern not only technology and network infrastructures, but also smart city organization and government. (Nam & Pardo, 2011.) There for smart city should evaluate internal and

external risks and reflect them to strategy and consider impacts to organization, financing, legislative issues and stakeholder relations. (COSO, 2016; Oulasvirta & Anttiroiko, 2017).

3.4 Stakeholder

The stakeholder theory observes stakeholder relations and describes how organization operates through stakeholder relations and how stakeholder interests and value expectations are considered and met. The stakeholder theory emphasizes to create value for its stakeholders in an effective way as it enhances the stakeholders´ commitment and responsibility. (Freeman et al., 2010; Jensen, 2001.) Freeman (1984) describes stakeholder "as any group or individual who can affect or is affected by the achievement of an organization´s purpose". The components of the quadruple helix and stakeholder value are covered in the stakeholder dimension.

3.4.1 Quadruple helix and stakeholder value

Triple-helix, university-industry-government, partnership has been the dominant collaboration model in the smart cities. Aim of the trilateral triple helix networks is to benefit the knowledge created in each organization and engender new innovations and innovation ecosystems (Etzkowitz, 2003). Industries´ interest in the smart cities is to experiment and employ new technologies in the real-life environment and discover new value creation and business opportunities. For public organizations like city and academia the smart city concept provides environment for developing and testing technologies, but also potential for new knowledge creation, service design and possibility to stimulate local economy and interdisciplinary research activities. In the smart city context it is emphasized to extend triple helix model to include people and civil society as the forth helix and form *quadruple helix* partnerships. In the smart cities the citizens are seen as co-creators and social innovators (Carayannis & Campbell, 2011; Komninos, Pallot & Schaffers; 2013; Petersen, Concilio & Oliveira, 2015) who may own such a social capital and knowledge from their livelihood (Lea, Blackstock, Giang & Vogt; 2015) that is valuable for improving the community´s living conditions and environment. By integrating local community and citizens to urban development the city strengthens bottom-up smart city development and improves technology acceptance among the citizens (Ballon et al., 2005; Lea et al., 2015; Schaffers et al., 2011).

Value proposition is associated with the stakeholder relations and business model design. Value is linked to benefits (Rescher, 1969) each stakeholder is seeking from the value networks and stakeholder relations. Received value may occur in the form of goods, services, financial profits, cost savings, knowledge or in improved quality (Allee, 2008; Sainio, Saarenketo, Nummela & Eriksson, 2011), but received value may further emerge in-directly in the value networks (Allee, 2008; Ojala & Helander, 2014; Ojala & Tyrväinen, 2011). Access to a new market or resources that otherwise are unreachable are examples of the in-direct value in the value networks (Ojala & Helander, 2014).

Smart cities are growing markets attracting multiple organizations and stakeholders. Despite of tremendous possibilities the smart city phenomenon creates, leading smart city from pilot stage to more mature level takes time and results may be realized with extended period of time. Smart city strategy, quadruple helix collaboration and ecosystem orchestration and management improve communication and trust among stakeholders and enhance to evaluate value propositions and business potential in the smart city projects.

4 Conclusion

This paper elaborated and presented smart city conceptual model (SCCM), which aim is to strengthen smart city design and ecosystem governance. The rationale for elaborating SCCM emerge from the perception that cities´ have inadequate capabilities to govern complex smart city ecosystems and manage rapidly changing digital technologies in city setting. Due to these reasons many nascent smart city projects perish after the project funding is used. Aim of the SCCM is to assist smart city practitioners to form long-term smart city vision and strategy, facilitate the governance of the heterogeneous stakeholder relations and digital technologies and to assist evaluate risks and funding needs. SCCM aims further to enhance the smart city stakeholders to outline and evaluate smart city projects and assist to unlock the barriers for business model innovation and value creation in the smart city ecosystems. SCCM consists of four main dimensions, strategy, technology, governance and stakeholder and their sub-components. SCCM dimensions and sub-components form meaningful interrelations and provide comprehensive approach to design smart city initiatives and ecosystems.

It is highlighted to integrate social, economic and ecological perspectives to enhance social sustainability in society (Eizenberg & Jabareen, 2017). One of the emphazised goals for smart city initiatives is to improve the quality of citizens´ lives. Including social and political aspects in the SCCM would extend perspectives for more resilient and sustainable smart city design. Further, indicators to measure and analyze smart city initiatives are emphasized to support the management and success of the smart city projects.

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