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A Systemic Approach to Risk Management for Smart City Governance

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Abstract. Smart cities offer much promise but also present many types of risk. There is a growing body of literature examining the benefits and downsides of smart cities including various categories of risk. Among the typical types of risks are technological, organisational and social. Of these, technological and organisational risks are most investigated and social risks are relatively less so. This paper presents a model of risk management for smart city governance based upon a systemic approach. The model draws upon a literature survey of risks identified within smart city projects from 2010 to 2021. The potential systemic risk was analyzed through the use a governance model which identifies the smart city as a system of systems (SoS), consisting of constituent systems: transport, energy, cultures, economy, education, health, with technology located as a central system. The risk model was carefully examined in the consideration of external factors acting upon the smart city, constraints upon the governing body, and how the feedback from the smart city to the governing body can help that body to fine tune its governance procedures for 'satisficing' results.

Keywords: smart city governance, systemic risk and risk management

1. Introduction

In 2010, more than half of the world's population lived in urban areas according to Dameri [1] and this figure will be likely to increase to at least 75% by 2050. Given this rise in the number of people who are residing in urban areas, municipal governments must manage an increasing assortment of technical, physical, social, and organizational issues arising when with large and complex groups of people must live in limited spaces. Growing urbanisation produces many problems that decrease the quality of life, including inequality, pollution, ageing populations, and insecurity [2]. Cities must find better ways to respond to these challenges; for example, traffic congestion, high crime rates, pollution, management and consumption of waste, and so on [3, 4].

The concept of the "smart city" is one novel and popular way to address the current difficulties experienced living in cities and is a method of rendering them more sustainable. The concept of the smart city was first proposed in the 1990s as a way of approaching some of the difficulties caused by rapid urbanization, often using information and communication technology (ICT) [5]. Studies have defined this smart city concept in a number of ways [6-8]. Within the realm of technology, some authors have emphasised the great potential that smart technologies can bring to urban systems, including smart grids and smart transport systems. ICT is often used as a backbone for smart city definition. Some definitions move away from the focus on ICT and attend instead to the equilibrium between technology, institutions and people [9].

Smart governance is of course a key characteristics of the smart city [10] and incorporates citizen participation in decision-making, in service provision, and in policy development [11]. In this way, the city can understand problems and can then manage these problems through sophisticated ICT. Smart governance occurs when stakeholders are brought on board with decision-making [12]. Technologies including open data and social media serve to build up and underpin the cooperation possibilities between citizens and their

governments [13], ensuring that operations and services are truly citizen-focused [14]. Current rapid developments in ICT can reform city governance into "smart governance" as it empowers governments to operate more efficiently and effectively [15, 16]. ICT provides great opportunities to encourage comprehensive and varied communication with citizens [13].

Local governments also face many issues including the need to create wealth but also to ensure sustainability. There is now significant pressure for cities to be green, to be safe, and this is despite limited resources spent for city development. Smart cities can become culturally vibrant when they integrate diverse groups from a range of different backgrounds. Limitations of knowledge and experience in local governments in developing smart cities is a critical issue. During the smart city development stage, there are potential risks in crossing social, technical, economic, political, and environmental domains, and this creates barriers in implementing strategic policy, as well as significant challenges for policy makers. This paper aims to investigate potential risks that may influence the effectiveness of the governance mechanism of a smart city; and proposes a systemic approach to the risk management within smart city governance.

2. Background

2.1. Conceptions of Smart City Governance

Several types of smart city governance have been proposed in the literature, including: (1) smart city government; (2) smart decision-making; (3) smart administration; and (4) smart urban collaboration.

Smart city government simply means governance of a smart city, with no need for significant changes in processes and structures. Smart governance therefore concerns making the right policy choices, implementing them effectively, and this can be achieved within the existing structures [17]. Smart governance is simply a characteristic that is associated with managing a smart city.

The second type, smart decision-making [18], is focused on the need for innovative approaches toward decision-making and implementation. There is no need to restructure organisations or institutions. Decision-making can be enhanced through the use of network technologies, and smart governance arises through the collection of data and information using sensors.

The third type, smart administration, requires that government should be more inventive, but at the same time they need to reduce costs, and operate in a highly connected world. These days, stakeholders require and even demand to have their input. ICT in government in this view can be seen as a way to reform administration at all levels: digital government is a transformational effort that will enhance efficiency and service delivery, and transform functions and practices through ensuring that the citizen is at the centre. This increases transparency, promotes openness, and reduces corruption. E-government strategies allow administrative efficiency and interoperability, which leads to improvements in service [19].

Smart urban collaboration, the fourth type, stresses that smart governance requires a repositioning of government. This entails a more community-based approach to governance. Governments of smart cities must proactively stimulate interactive participatory involvement. Bătăgan [14] asserts that 'smart governance means collaborating across departments and with communities, helping to promote economic growth and at the most important level making operations and services truly citizen-centric'. Pereira, et al. [19] investigated the use of ICT in improving administrative efficiency, based on the citizen and strong service delivery. ICT is now a facilitator of new relationships wherein citizens' concerns are more important in forming policy. It becomes possible to develop smart governance when the government coordinates the efforts of all stakeholders. Technology enables governments to be transformed through their interactions with both people and businesses.

2.2. Typical Approaches to Smart City Governance)

Several typical models of smart governance have been proposed in the literature: some of them are of the top-down style and others are bottom-up in style. There are also some mixed hybrid styles of governance.

The top-down approach provides ICT-based architecture that can monitor people's activities, as well as interacting with infrastructures. The gathering of these data enables adjustments in accord with predetermined benchmarks. This is an optimisation-through-technology approach, in which public services

are shaped by the government and at the same time people can put forward their suggestions and opinions. The shortcoming of this top-down style is that this approach, focused as it is upon control, may limit freedom, privacy, and the potential for innovation.

The bottom-up approach, on the other hand, involves robust input from the people who live in the city. This is possible through techniques including codesign with stakeholders, co-funding, co-delivery, and co-evaluation [20]. A bottom-up approach is likely to produce concrete actions that can address citizens‘ problems directly [21]. However, one shortcoming is the possible conflict that can arise between decision-makers, urban planners and the views and wishes of the people themselves. In fact citizen empowerment and bottom-up approaches are often neglected [22].

Alawadhi and Scholl [5] focused their attention on the four recent smart city initiatives of Seattle, Munich, Turin, and eCityGov alliance. Seattle and Munich used hybrid governance models with stakeholder participation at various points in the process; eCity used a more top-down governance style. Whichever model was, utilised, each of them involved some collaboration, information sharing, and consensus-based decision-making. Castelnovo, et al. [23] proposed a holistic citizen-centric approach, centred around community building. Focusing purely on ICT is insufficient. Thus inclusiveness and equal opportunity, as well as citizen participation, need to be embedded in the process of digitisation.

2.3. Smart City Governance Challenges Potential Risks

All innovations have opportunities and risks. A smart city characterized as an innovation is like a living laboratory for a real-life experiment [17], and this necessarily entails risks that will be unavoidable, given that practices introduced are new and untested. A smart city initiative is not only an innovation driver, but also needs to manage risks involved in implementation and governance. Developing a smart city leads to an increase in the complexity level of the whole system. The initiative of developing a smart city extends beyond technology, and involves integrating technology, people, capability, and global reach into systems that are sufficiently complex for unexpected emergent properties to develop [62]. Risks arising from innovation include technology risks such as lack of knowledge and overoptimism; organisational risks including conflict, resistance to change and projects that are not lined up with organisational goals; and policy risks that include lack of adequate consideration of various stakeholders, political pressure from various quarters, and conflict between policies. This creates a pressure in seeking a new approach to manage potential risks during the process of smart city governance.

3. Research Method

The literature review was undertaken in three phases. The first phase retrieved a broad range of papers through an advanced search query in Web of Science, Scopus and ScienceDirect. The term ‘smart city governance’ was used to retrieve articles, conference proceedings, books, book chapters, and doctoral theses during the period of 2010 - 2021. This period was selected because of significant contributions of scholars to smart city literature. The second phase of the literature review refined the search. Abstracts and introduction sections were analysed, and articles of a specific technical nature were not considered. This second phase produced a sample of 80 research outputs. In the third phase of the literature review, papers selected in the second phase were read and those that were relevant to the research question retained in the database. Next a qualitative content analysis was undertaken. The final database consisted of 31 papers published in international journals, books, conference proceedings or other research outputs.

4. Findings and Discussion

4.1. Initial Risk Identification of Smart City Governance

The wide variety of risks involved in developing smart cities have been picked up by several authors. Galdon-Clavell [22] commented that at that time there had been an insufficient consideration of the limits and risks that smart technologies may bring. One of the most obvious risks concerns the widespread nature of data gathering and data sharing. With the proliferation of smart technology there will be a greater awareness of the various risks and increased pressure for developers to consider privacy enhancing technologies and frameworks. Concerns with data privacy are widespread currently, especially given

increasing use of surveillance enabled technologies. People have also been concerned about the dual use of these technologies: that is, their use being extended to domains in which they were not intended to be used. This author suggests that continuous monitoring will be needed to minimize inappropriate use of data by third parties.

Hämäläinen and Tyrväinen [24] presented a smart city conceptual model and identified the criticality of risk management in smart city governance. As they say, smart cities are vulnerable to external uncertainties and need to be created in a strategic way that considers the development over the longer term. A smart city strategy will analyse the macro environment and evaluate feasibility of new developments and the resources they will need for implementation. A variety of IoT technologies have been employed in smart cities across domains such as traffic, air quality, health data and services, social security, and business. Transforming to a smart city will be a complex process that takes time and requires collaboration between the various stakeholder groups which in turn requires suitable governance. Smart cities need strategic risk management for risks associated with technology, the smart city organization, and its governance. Smart cities need to plan for cyber security.

A recent literature review by Ismagilova, et al. [25] looks at studies that focus on security, privacy and risks within the context of smart cities and some of the challenges arising. In terms of privacy and security of mobile devices and services, these authors point out that there are approaches that may assist in providing privacy, including foggy dummies, a blind third-party where a trust relationship is developed to protect the user from the server provider, and a double foggy cache to solve the trust issue between peers. The vulnerability brought about by IoT-based applications is related to the network in which they live and key interactions within that network. Collecting and transferring data using IoT devices can have a severe impact on security and privacy within smart cities unless precautions are taken. Given high levels of interaction between people, devices and sensors, there is a strong need for data to be fully protected and for effective risk management procedures to be unfolded. Smart power systems represent another aspect of security and privacy concerns, because agencies connected to the grid can monitor usage patterns and predict consumers' behaviors, which again is a security risk. Hiding individual consumer characteristics via a particle swarm optimisation process has been suggested. Security within health care services is another important issue to be managed. Key threats regarding personal health data captured via sensors need to be addressed, perhaps through the data owner being able to authorise third-party analysis. Data in smart city applications have the basic needs for confidentiality, integrity, availability, non-repudiation, control of access and control of privacy. Obviously, perceptions about security and privacy will be critical in encouraging people to use smart services. These authors conclude that significant challenges remain regarding privacy, security, and risk for many stakeholders. There are vulnerabilities that are open to exploitation by third-party organisations. Trust is critical and the huge amount of data that is processed within the smart city means that authorities must balance data analytics with individual rights to maintain citizens' trust in governments.

Another study in the same year, that of Shayan, et al. [26] considers the first two decades of research on smart cities on the topic of risk. As they comment, smart cities present unprecedented risks and challenges. Their systematic review identifies various categories of risks. There were at that time 250 smart city projects in 178 cities globally. They comment that: "Despite a significant number of relevant studies in the literature, actual inclusive evidence for smart city risks has not been provided and hence been identified and understood." Their analysis of 85 papers from around the world indicated three major categories of smart city risk factors: organisational, social, and technological. Organisational risks consist of lack of competency by authorities, organisations which are over technologised, and city management processes that are too complicated. Social risks involve conflict between stakeholders, lack of trust by people in the new technologies, lack of desire to participate in smart cities by some people, growth of unemployment, a digital divide between citizens due to their differential competencies in ICT, and gentrification of smart cities due to their higher costs. Technological risks involve cyber security, threat of data loss, smart systems being incompatible with other less-developed regions, and repair and maintenance of smart technologies. The authors comment that most papers they surveyed investigated technological risks, while fewer articles addressed organisational and social risks. This finding seems to be quite common in literature.

Ullah, et al. [27] also examined risks that make the governance of smart cities more difficult and indeed susceptible to manipulation. Their literature review of 796 articles identified a total of 56 risks, which they then grouped into technology/organisation/environment categories. They identified 17 technological risks including IoT networks, public management of the Internet, and users' concerns about safety. Organisational risks are less frequently identified, and they are about user data security, customer management, governance, and cloud management. They propose a multilayered framework to help governments manage the risks involved in smart city governance. Introducing new technologies overall can have a positive impact [28]. In terms of technology related risks, disruptive technologies must be adopted if cities are going to transform themselves into smarter and sustainable cities [27]. However this introduces many risks and these need to be identified and managed effectively.

A paper by Tan and Taeihagh [29] considers the special circumstances of developing countries and the particular risks that can arise there. In their literature review, they talk about the need to develop trust through privacy laws and clear arrangements for data collection and sharing. Economic stability is always important in developing countries and financial risks will be a factor for investors in considering investing in a smart city project. Lack of suitable infrastructure is another issue for developing countries, along with lack of appropriate governance frameworks and regulatory safeguards, in which case risks such as identity theft, data theft and cyber security attacks can easily occur. Lack of suitably skilled human capital is another area of risks. All these risks pose problems for developing country given limited financial resources available to provide the infrastructure and manage the risks. The interaction between such risks would pose much greater danger.

Academics and practitioners agree that traditional governance is insufficient for smart cities, given the demands on public decision-making based upon the complexities present when we see a clash of technology, politics and values. Traditional risk management is also inadequate in dealing with complex system of systems such as a smart city; thus a holistic approach to risk management should be in consideration.

4.2. Systemic Approach to Risk Management for Smart City Governance

Systemic risks occur when an individual event turns into a systemic event with much wider implications. This occurs due to the interconnectedness of institutions. With systemic risk, the total risk is much greater than the sum of the risks caused by the individual systems alone, because it includes the effect of uncertainty on the whole complex project or system. Systemic risk adds up to more than the sum of the individual risks, since it includes all sources of project or system uncertainty. This term is often related to financial adverse events, but can be applied to other domains as well. Resiliency of a system or project will depend upon how individual risks interact together to produce either opportunities or cascading failures. Systemic risk is caused by emergence due to uncertainty, complexity, ambiguity, and volatility. When considering the smart city as a system of systems, clearly there will be interrelationships between the risks associated with each of the constituent systems and these risks could easily result in a failure situation.

Figure 1 presents a model of risk management for smart city governance based upon a systemic approach. This proposal is based on the work of Gorod, et al. [30] and Mansouri, et al. [31], who had significant contributions to governance framework development for complex systems. At the top of the model is the system of systems of the smart city which consists of several constituent systems: energy, transport, health, education, economy, culture, and technology. Each of these systems will have their own risks and as the systems interact with other systems within the system of systems of the smart city, these risks will interact producing systemic risk. For example, economic pressures will cause risks to the financial system, and this may have very been impacts on the health system, with risks to people's health and well-being.

The model also shows the governing body of the smart city, which is the municipal government. There are External factors acting upon the smart city, such as legal and policy factors, the natural environment, and technological factors outside of the system. There are also Constraints upon the governing body, such as constraints about knowledge, lack of time, budget constraints and cultural constraints which may limit the kind of governance mechanisms which will be accepted. The diagram also shows that the governing body takes feedback from the smart city system of systems, considers that feedback, and produces a governance response to improve the smart city performance.

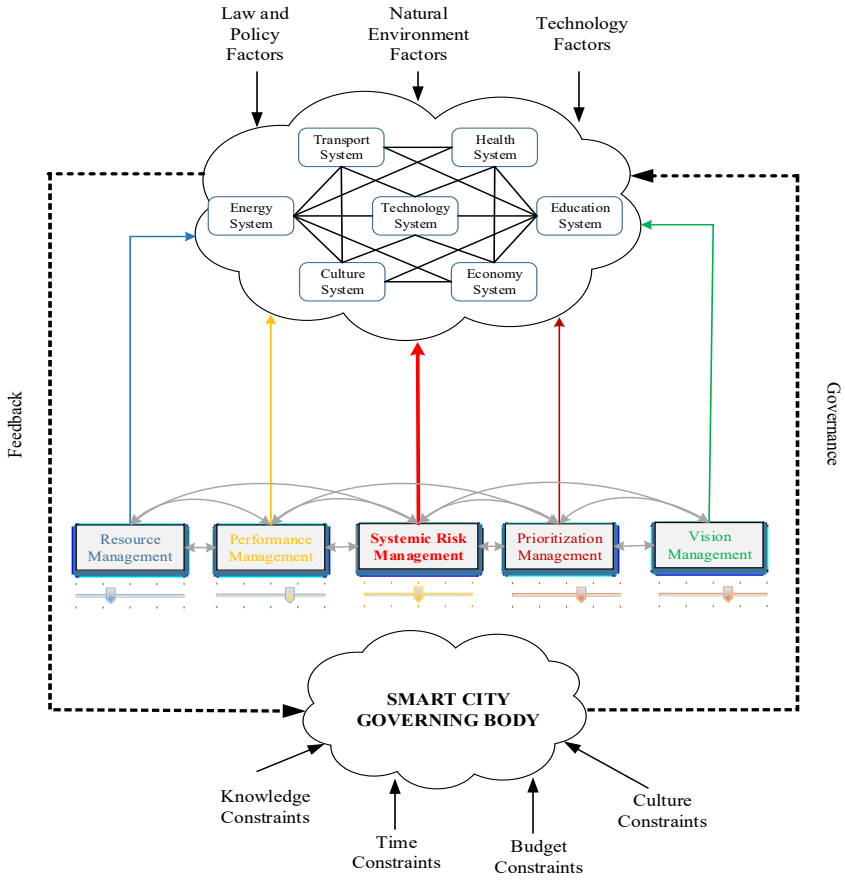

Fig. 1. A systemic approach to smart city governance. Adopted from Gorod, et al. [30] and Mansouri, et al. [31].

Also inside the diagram are five risk factors: resource management, performance management, risk acceptance level, prioritisation management, and vision management. Clearly, when considering systemic risk, other factors will impinge upon the risk result. For example, if we change the resourcing level, we will more than likely have an impact on a number of the systems inside the smart city. If we decide to accept a lower performance level or require a higher performance level, this will have an impact upon the systems inside the smart city itself. Risk acceptance level is obviously an issue that must be considered when determining governance approaches to the smart city. Prioritisation management will have its impact as well. The strategic vision that one has about the smart city will also influence risk approaches. How smart is the city intended to become? If it is a highly sophisticated smart city, this will involve a different approach to systemic risk than if the approach is to be a basic one. These various risk factors can be fine-tuned individually by the governing body according to resources, performance, priorities et cetera to produce governance instructions and policies for the smart city system of systems.

In such situations, the SoS approach, together with modelling and simulation techniques, can provide risk scenarios of smart cities via modelling the interaction among constituent systems. This approach will be useful in determining the impact of the levels of the various factors that are decided upon by the governing body in its instructions to the smart city. Modelling and simulation can be employed to give information to policymakers regarding the impact of systemic risks on the whole system. If inputs are changed, that would change the risk analysis. If, for example, more resources are provided, then the modelling and simulation will show the impact on the risks to the constituent systems and to the smart city itself.

5. Conclusion

Today‘s cities are totally transformed under the pressure of rapidly increasing urbanisation and increasing stakeholder expectations. Smart cities provide a great chance for the transformation of people’s quality of life, based on the advantages of information and communication technology (ICT). Literature on the topic of smart cities has burgeoned over the last two decades and many papers have discussed the risks involved in such projects, especially technological risks. What previous research has not done is to consider

systemic risk that occurs when various consituent systems interact with each other under the System of Systems (SoS) perspective. The SoS approach provides a new perspective for considering potential risk under the holistic view of a complex system, with its network structure and many interactions. This also highlights the need to develop a new framework for the systemic risk management within smart city governance. The contribution of this paper is to introduce the concept of the smart city as a complex system of systems, and then to explore a methodology for responding to systemic risks during smart city development and governance.

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