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RESEARCH ARTICLE

Perspectives of smart cities in South Africa through applied systems analysis approach: a case of Bloemfontein

Dillip Kumar Das

The Discipline of Civil Engineering, School of Engineering, Howard College, University of KwaZulu Natal, Durban, South Africa.

***Corresponding author:** Dillip Kumar Das, The Discipline of Civil Engineering, School of Engineering, Howard College, University of KwaZulu Natal, Durban, South Africa.
Email: dasd@ukzn.ac.za

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Abstract

There is a changed perspective regarding the development of cities and increasingly many countries in the West and some developing countries, as in South Africa, are making concerted attempts to transform their cities to smart cities. Using the context of the city of Bloemfontein, South Africa and drawing on the perceptions of stakeholders, the objective of the paper is to offer a perspective on such a transformation. The study first assessed the performance of various factors and attributes that influence three important aspects of a smart city: economy, mobility and governance system. It then recorded the viewpoints of stakeholders about how these aspects can contribute to the development of a smart city. Further, Applied Systems Analysis (ASA) linked System Dynamics (SD) conceptual models based on the interlinkage and causal feedback relationships among various factors under each aspect were developed, which could assist in offering perspectives that would enable eliciting of policy interventions to develop smart cities. Findings indicate that there are potentials and positive indicators in all three aspects. It is emerged that reinforcement of the inter-relationship among entrepreneurship, innovation, productivity, economic image and international embeddedness will foster a smart economy. Efficient public transportation and advancement of Information Communication Technology (ICT) system will strengthen local accessibility and ensure an innovative, sustainable and safe transportation system that will result in smart mobility. Effective participation of stakeholders in the decision-

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making process alongside the elected city council and transparency will aid smart governance. The combined effect of these attributes should enable the transformation of the city to a smart city.

Keywords:

Entrepreneurship; Governance; People's participation; Public transportation, Information Communication Technology.

Introduction

Cities across the world are observed to have evolved over time. Many cities have been transformed from one state to another, in terms of size, functions, and characteristics. For example, some cities have grown from a small and humble centre to a large or sometimes to a megacity. Some cities have been transformed from uni-functional cities to multifunctional cities - for example, a city that starts with an administrative or governance function but develops to encompass social, economic and industrial functions. Although the transformation of the cities is natural, there have been also concerted and deliberate planned efforts to attain qualitative transformation, such as making cities functional, liveable, efficient and, more importantly, sustainable (Marsal-Llacuna, 2016; Yigitcanlar, et al., 2019a). However, in recent years, a new trend has emerged that some existing cities have been transformed to make them 'smart', and initiatives for the development of several new smart cities have been taken (Batty et al., 2012; Das, 2017; Townsend, 2013; Yigitcanlar and Kamruzzaman, 2018).

Before the emergence of the smart city concept, different approaches have been attempted to augment various development attributes in the cities, depending on the opportunities and potential they offer. In the process, concepts such as pioneer cities, digital cities (Yovanof and Hazapis, 2009), connected cities (Batty, et al., 2012), entrepreneurial cities (Kourtit and Nijkamp, 2012; Thite, 2011), liveable cities (Caragliu, del Bo, and Nijkamp, 2011; Nam and Pardo, 2011; Praharaj and Han, 2019) and so on have emerged. Furthermore, recent technological advancements have added opportunities for realising such concepts. In this context, scholars have argued that cities should be developed in such a way that it will bring economic, social and infrastructural advantages (Batty, et al., 2012; Batty, 2015; Datta, 2015; Harrison and Donnelly, 2011; Moussiopoulos, et al., 2010), offer possibilities for creating safe and healthy living conditions (Moussiopoulo et al. 2010), enable judicious resource-use (Batty, et al., 2012; Harrison and Donnelly, 2011), enhance connectivity (Townsend, 2013), assist in reducing energy consumption and wastes, and create an atmosphere for an enjoyable lifestyle (Batty, et al., 2012; Datta, 2015). Consequently, arguments have emerged to take the cities beyond sustainability and make them economically, socially and environmentally smart (Batty, 2015; Datta, 2015; Giffinger, et al., 2007; Harrison and Donnelly, 2011; Townsend, 2013).

Many South African cities offer the potential for both economic advancements and appropriate spatial development and municipalities have already been proactive in promoting an agenda of economic, social and environmental sustainability. Beyond sustainability, there is a political will to move to make policy interventions towards achieving smart cities. (Areff, 2019; Das and Emuze, 2014). Arguments have emerged that this should be based on a balanced interlinkage between sophisticated digital solutions and expectations around the economy, infrastructure, environment and services that meet basic human demands and aspirations (Areff, 2019; Das and Emuze, 2014). This demands a critical assessment of opportunities and demands of each city that aspires to transform to a smart city. Therefore, using the study context of Bloemfontein city, this paper provides a perspective of how existing cities can be transformed to smart cities in South Africa. For this purpose, the paper first assessed the performance of the various factors and attributes that would influence the three key aspects of the economy, mobility and governance (local) system. The study developed Applied Systems Analysis (ASA) linked to System Dynamics (SD) conceptual models based on the interlinkage and causal feedback relationships among various factors under each aspect to engender dynamic hypotheses that assist in developing policy interventions. Furthermore, the study recorded stakeholder viewpoints, through a perception survey and focus group discussions, on how these aspects can contribute to the development of a smart city, in other words, to evaluate the performance of and establish causal relationships amongst various factors and attributes under the three mentioned aspects. This was done because of the unavailability of structured data, which is a limitation of the study.

Literature review

The study entails to two specific aspects: (1) the perspectives of development of smart cities in the South African context and (2), application of the ASA paradigm to build conceptual SD models to comprehend the perspectives. Therefore, the literature review is specifically contextualised on these two aspects to provide theoretical underpinnings to the study.

SMART CITY PERSPECTIVES

There is no universal definition(s) of a smart city. An array of issues, such as Information and Communication Technology (ICT), ubiquitous connectivity, knowledge and creativity, big data and open data, social capital, business and entrepreneurialism, smart community, ecological sustainability, etc., have been used to characterise the smart city discourse (Harrison and Donnelly, 2011; Praharaj and Han, 2019). Several rather different schools of thoughts and different approaches to building smart cities have emerged that vary according to the context and perspectives.

According to one predominant school of thought, a smart city is an instrumented, interconnected and intelligent city that enhances efficiency in various urban activity facets through the use of advanced and digital technology (Cavada, Hunt and Rogers, 2014; Datta, 2015; IBM, 2008; Praharaj and Han, 2019; Townsend, 2013). For instance, a smart city – Songdo in South Korea – is developed to foster sustainable design practices through the incorporation of the latest technologies that reduce energy consumption and increase energy efficiency, utilize recycled and natural materials and generate clean or renewable electricity (Yigitcanlar, et al., 2019b). PlanIT Valley in Portugal is conceptualised to combine intelligent buildings, transport, built environment information and energy systems with enhanced mobility, parking and emergency services (Cavada, Hunt and Rogers, 2014; Living-PlanIT-SA, 2013). Similarly, in India, Dholera is planned or being developed with seamless integration of urban planning with digital technologies as the most sustainable solution to rapid urbanization, with an expectation of creating a new city without the annoyances of everyday urban life (Datta, 2015). Moreover, alongside technology, other fundamental characteristics that have been underlined are competitiveness and productivity (Kourtit and Nijkamp, 2012), creative economy (Thite, 2011), urban place marketing and business-led urban development (Sokolov, et al., 2019); self-branding and image building to attract businesses and the creative class (Hollands, 2008; National Geographic, 2015).

Besides, an alternative smart city narrative has emerged, which projects it as a human concept, focussing on social innovation (Nam and Pardo, 2011; Caragliu, del Bo and Nijkamp, 2009), smart citizenry (Coe, Paquet and Roy, 2001; Griffinger, et al., 2007), learning and knowledge capital (Yigitcanlar, O'Connor and Westerman, 2008) and inter-organisational collaboration. Linking these two concepts of smart city, scholars like Kitchin (2014) perceive that a smart city is increasingly composed of and monitored by pervasive and ubiquitous computing and its economy and governance are driven by innovation, creativity and entrepreneurship enacted by smart people (Kitchin, 2014).

According to another school of thought, the smart city concept is derived from the combination of concepts of the Connected city (smart logistics and sustainable mobility), the Entrepreneurial city (economic vitality), the Pioneer city (social participation and social capital), and the Liveable city (ecological sustainability) (Giffinger, et al., 2007; Komninos, 2002; Lombardi, 2011; Nijkamp and Kourtik, 2011; Shapiro 2008). Such a smart city has six characteristics: smart economy, smart people, smart mobility, smart environment, smart governance and smart living. In this case, the smart city is not considered holistically but rather refers to aspects that range from ICT (Digital) districts to smart populace in terms of educational level (Giffinger, et al., 2007; Komninos, 2002; Lombardi, 2011; Shapiro 2008). In other words, a smart city must be smart and perform efficiently in these six important aspects of the city independently or in combination (Das and Emuze, 2014; Giffinger, et al., 2007).

Essentially, smart cities can be construed as those in which technologies, ubiquitous computing and digitally instrumented devices are built into the very fabric of urban environments, which monitor, manage and regulate city flow and processes; engage with place, activities and people – often in real-time (Greenfield, 2006; Hollands, 2008; Kitchin, 2014). This, in turn, enhances economic efficiency and environmental sustainability, creates a unique image and offers appreciable living conditions, and most importantly should be managed by a participative and inclusive governance system (Hancke, Silva, and Hancke Jr., 2013; Sokolov, et al., 2019; Townsend, 2013).

However, unlike the western counterparts, a different narrative has been emerged in developing countries such as India. According to Government of India (GoI, 2015), a smart city in India would have a different connotation than its western counterparts. This revolves around how best to meet the aspirations of a city dweller when it comes to infrastructure and services that range from improving the essential services through the supply of adequate clean water, upgrading sanitation and the solid waste management system, making available 24/7 power supply, and strengthening urban mobility. Also, along with the provision of these infrastructure and services smart cities are expected to reinforce economic performance, enhance energy efficiency and reduce environmental pollution (Praharaj and Han, 2019). In contrast, cities like Dholera are being built to become competitive global cities, an urban utopia led by smart technologies to create economic enterprises so as to leapfrog or at least compete with the more mature economies (Datta, 2015; Kitchin, 2014). Thus, a strange duality in the perspectives has been seen.

Despite the lack of unanimity of the concept of a smart city, the primary goal is to create an urban environment that offers services for a high quality of life to its residents while also generating overall economic growth and reducing environmental degeneration (Batty, et al., 2012; Harrison and Donnelly, 2011; Shea and Burns, 2016). Moreover, it uses ICT to increase its operational efficiency, share information with the public, and improve the quality of government services and citizen welfare (Areff, 2019).

In South Africa, certain studies with regards to different aspects of smart city have been conducted. For example, premised upon the study on the ranking of European middle-sized cities, Das and Emuze (2014) assessed the potential and opportunities of a city based on the performance of six smart characteristics of a city. A further study examined how safe and sustainable road transportation can be achieved by smart mobility (Emuze and Das, 2015). The augmentation of the economy, mobility and governance have been argued to be a critical step in this transformation (Areff, 2019; Das, 2015). It was also stressed that location of the ICT and related industries in the cities of South Africa will revitalise the economy of the cities that might lead to a smart economy, which is an essential element of a smart city (Das, 2019). Another study (Das and Emuze, 2020) explored the politico-cultural dimensions and argued that people and governance are the two important dimensions, which should be considered while developing smart cities. Thus, for a smart city, three essential aspects such as smart economy, smart mobility and smart governance are highlighted. This study builds on these studies in assessing how these aspects are currently performing in a South Africa city (Bloemfontein) and in developing a viewpoint on how these aspects can contribute to transforming the city to a smart city.

The economy for a smart city revolves around such elements as innovation, entrepreneurship, branding, productivity and flexibility of the labour market as well as integration in the national and international market (Griffner, et al., 2007; Van der Weijden, Chraibi, and Rajagopalan, 2017). The focus of the smart economy in a city is aimed at creating equal opportunities for its people and to engender a conducive environment for increased work opportunities (Kummitha, 2019; UN Habitat, 2016). This includes the creation of entrepreneurial opportunities through the use of technological innovations and participation of stakeholders (for example, public-private partnerships) that not only promote corporate sector but also small and medium and social enterprises (Almirall, et al., 2016; Mclaren and Agyeman, 2015). The economy should moreover be inclusive, safe, resilient and sustainable (Kummitha, 2019; Allam and Newman, 2018), which need to be at the forefront of city development in South Africa (Das, 2015; 2019). Local and international accessibility in the form of a sustainable physical transportation system and ICT refers to mobility, which is of paramount importance (Griffner, et al., 2007; Hemel, 2018; Sokolov, et al., 2019). Reinforcing of local accessibility through quality public transportation, enabled and operated by ICT remain vital for smart mobility. Moreover, while intelligent transport and autonomous vehicles are likely to be the backbone of the mobility services in future (Chehri and Mouftah, 2019; Haboucha, Ishaq, and Shiftan, 2017), low carbon emissions, traffic safety, use of economical and low carbon emission cars are the important determinants of smart mobility in a city (Emuze and Das, 2015), which are major challenges in South Africa (Das, 2015; Emuze and Das, 2015). The new paradigm of life in society such as a smart city requires a process of governance that is premised upon innovations, creativity and planning to meet the societal challenges (Guimarães, et al., 2020). Arguments have emerged that technologies such as ICT can influence and be useful to meet various societal and governance challenges, for example, participation of people in decision-making, provision of infrastructure and services, management of environment (Gil-Garcia, Helbig and Ojo, 2014; Schwab, 2017). So, governance, in terms of political participation, services for citizens and the functioning of the administration, are of primary importance to build smart cities (Boyko, et al., 2012; Guimarães, et al., 2020; Hunt and Rogers, 2016; Sokolov, et al., 2019). People's participation, community engagement and inclusiveness in the local governance system have been identified as critical issues in South African city development (Das and Emuze, 2014).

Understanding the positioning of South Africa both in terms of advanced technological leadership point of view and the challenges of economy, mobility, and governance, this study is contextualised within a middle-sized city of South Africa. The scope of the study is confined to the three predominant challenges – economy, mobility and governance, with regards to transforming the city to a smart city.

EPIGRAMMATIC OUTLINE OF APPLIED SYSTEMS ANALYSIS AND ITS APPLICATION FOR DEVELOPMENT OF SMART CITIES

A city is considered as a system (Chadwick, 1971, pp.36-37; Checkland, 1981; Forrester, 1969). Accordingly, a city as a system constitutes a set of subsystems or in other words components, for example, people, land, governance, mobility, technology, environment, and so on, which are interlinked and interdependent on each other to perform a function as a whole (Bertalanffy, 1974; Chadwick, 1971, pp.36-37; Checkland, 1981; Forrester, 1969).

Applied System Analysis (ASA), which is essentially premised upon systems theory, is construed to be an appropriate method for modelling principles used to comprehend the behaviour of the complex problems of independent urban subsystems or a city as a whole system (Beck, et al., 2018). ASA is a modelling principle that is multidisciplinary and cross-disciplinary and can deal with complex problems having (or without) causal (feedback or no feedback) relationships. It provides a holistic approach in finding solutions to complex problems (Beck, et al., 2018; Laszlo and Krippner, 1997). Further, according to scholars such as Forrester (1994) and Lane and Oliva (1998), the rigorous structural framework provided by Systems Dynamics (SD) modelling principles assists to build causal feedback relations and consequent conceptual models, which can elicit the behaviour of the various complex problems of a system or subsystems and in this case a complex socio-economic system of a city. Literature also evidences that the ASA premised SD modelling principle, although generally quantitative in nature, can also be used qualitatively to comprehend the challenge in understanding complex urban problems (Beck, et al., 2018; Emuze and Das, 2015; Lee, Choi and Nam-Hee, 2005; Robinson, 2008). Since a smart city as a system has various subsystems (components) that are interlinked and interdependent and relate to complex socio-economic problems, ASA linked to conceptual SD modelling is suitable for analysis and evolving policy interventions (Beck, et al., 2018). Furthermore, the potentials of the SD modelling principles to cater for the feedback relationships make it more suitable to elicit the causal feedback relationships among the various influential variables, which assists in understanding the dynamics of the city system (Beck, et al., 2018; Forrester, 1994).

Study context and research methods

STUDY CONTEXT: BLOEMFONTEIN CITY

Bloemfontein city is taken as the case study for investigating the possibility of developing smart cities in South Africa. Bloemfontein city is among the growing medium-sized cities in the country. It is the capital city of Free State province, having a population of about 500 000 (Statistics, SA, 2011) and located almost at the geographical centre of the country. Functionally, it is also one of the three national capitals of the country, as the judicial Appellate and Supreme Court of the country are located in the city. Two universities offer tertiary education to almost 50 000 students. Several privately-owned high level and advanced hospitals and health care centres, in addition to government-managed hospitals, are available in the city. The city is connected to all parts of the country by all three modes of transportation, road, rail and air. An international airport provides connecting flights to major cities of South Africa and abroad. Besides, it houses several regional centres of business corporate houses and professional institutions.

As observed, the availability of adequate basic urban infrastructure facilities, including the existence of road transport and communication services, presence of skilled manpower and its proximity to Johannesburg, the largest city of South Africa and Pretoria, the administrative capital city of the country, have attracted a few domestic and multinational industrial companies. Moreover, the presence of the Information and Communication sector and internet are well felt in the city as most areas in the city are well connected through ICT.

However, the growth of industrial activities, influx of population and enhancement of tertiary (service-related) functions are increasingly creating pressure on the environment, urban infrastructures, and services. Besides, there are major challenges of public transportation for local accessibility. A thorough discussion with several stakeholders, members of the metro municipal council and urban development experts and review of the Integrated Development Plan (IDP 2017) suggested that the economy, mobility and governance need to be prioritised and could be important considerations for transforming the city to a smart city. Therefore, the scope of the study is limited to examine the three above aspects for exploring its perspectives to become smart.

RESEARCH METHODS

The study is premised upon the philosophy of epistemological interpretivism (Creswell, 2017; Saunders, Lewis and Thornhill, 2016). In this context, both phenomenological and symbolic interactional approaches have been adopted. Adoption of such an approach was essential because the study relied on the perceptions of the people based on their engagements and experiences and interpretations of the focus groups due to the lack of availability of structured statistical data pertaining to various urban development parameters including the three aspects such as economy, mobility and governance. Moreover, the study is aimed at creating new, richer understandings and interpretations of the complex problems within the context of developing smart cities. For this purpose, conceptual SD models premised upon the ASA paradigm were developed and used. This approach was deemed to be suitable as it has the ability to elicit causal feedback relationships based on real-world information (both subjective and objective). It offers a holistic viewpoint of the working of a system and generates dynamic hypotheses that could be used to generate the behaviour of a system (Robinson 2008; Wolstenholme 1992), in this instance a city system.

Conceptual models for the three above mentioned aspects were built independently to understand the perspectives of the three aspects of smart city development. However, before the conceptual models were built, a survey among key stakeholders was conducted to obtain their perceptions on these three aspects of the city, based on their experiences and engagements. The perceptions were used to evaluate the performance of the various indicators that significantly influence these three aspects of city development. The conceptual models were built by using interlinkage and causal feedback relationships among the various influential variables related to each key aspect. Furthermore, two focus group discussions were conducted with 22 and 17 participating members respectively, which are found to be adequate (Nyumba, et al., 2018). The members participating in the focus groups included urban planning professionals and consultants, ASA modelling experts, personnel belonging to the ICT industry, personnel belonging to Non-Governmental Organisations (NGO) engaged in city planning and development activities, municipal officials, academics and researchers of urban development, and common people. The focus group members were selected based on their engagement and involvement in the city development process at the national and city level, expertise in ASA and ICT industry. A list of potential participants was prepared based on their professional profiles. After, initial scrutiny, contacts were established to invite relevant and potential respondents to participate in the focus group discussions. The available and willing respondents were then invited to the focus group discussions. In the first focus group discussions, the survey results (the performance of the various factors and attributes) on each aspect were discussed and verified. Moreover, perspectives on different aspects for smart city development were discussed and opinions were gathered. The second focus group discussion addressed the verification and validation of causal relations and conceptual models.

The details of the data collection, data analyses and conceptual models are discussed in the following subsections.

Data and analysis

A household survey was conducted to collect primary data regarding demographic, economic, transportation and communication and governance scenarios of the city, which was used to evaluate the performance of the various development attributes of the city. The household survey was resorted to because there no structured statistical data was found to be available. Moreover, a household data survey was expected to provide adequate and relevant information at the grassroots level. The survey was conducted in six selected areas, Hiededal in the East, Langenhoven park in the South West, Fichardpark and Fauna in the South, Pentagonpark in the North, and the CBD area, out of more than 35 suburbs of the city. These suburbs were selected based on their geographical location, population and demographic composition, level of development, and influence on the city development process and expected to represent the city because of their heterogeneous attributes and characteristics. A systematic stratified random sampling method was used for selecting the households. To select the households, first, a list of households located in the suburbs were collected and scrutinised. Households were then stratified according to the streets. Also, the number of households to be surveyed in each street were decided proportionally. Sample households for the survey were selected at a particular interval of houses located in the selected streets of the suburbs. However, if one household was absent or unwilling then the next household was surveyed. Pre-tested questionnaires and semi-structured direct interview method were employed to conduct the survey and collect data. For this purpose, a sample size of 380 selected households was surveyed with the number of households varying from 60 to 70 households in each selected suburb. The sample size is found to be adequate for a population of 500 000, with a confidence level of 95% at a confidence interval of 5.03 at the worst-case percentage, 50%. The respondents were from all walks of life in the city, such as common citizen, merchants, businessmen, entrepreneurs, academics, students, government officials, people working in industries and enterprises, etc. To avoid bias, no discrimination based on gender race, education, income level, health conditions or status was made while conducting the survey. All ethical protocols were adhered to while collecting the data. The survey questionnaire included peoples' perception regarding the performance of different factors that influence each of the three aspects (economy, mobility and governance system). The attributes and factors under each attribute were identified from the published literature based on their relevance and influence on the city development process (Camboim, Zawislak and Pufal, 2019; Coe, Paquet and Roy, 2001; Das and Emuze, 2014, Emuze and Das, 2015; Giffinger, et al., 2007; Moussiopoulos et, al. 2010; Praharaj and Han, 2019; Shapiro, 2008; Sokolov, et al., 2019), and included in the questionnaire for their performance evaluation. The relevance and importance of these factors and attributes were checked and contextualised after discussion with experts and professionals belonging to urban development field. For example, there are 16 factors under six attributes (Table 1) that influence the smart economy, which were included in the survey questionnaire. Respondents were asked to assign their perceptions on a seven-point scale ranging between -3 and +3 (-3 representing the worse performance, +3 the maximum performance and zero neutral) (Das and Emuze, 2014, Giffinger, et al., 2007). Similarly, data on the performance of the factors under the aspects of mobility and governance were collected from the respondents.

Further, secondary data (statistical and time series data) were collected from published and unpublished literature, such as reports and the review of Integrated Development Plan 2017 (IDP, 2017) for the Mangaung Metropolitan Municipality (administrative authority of Bloemfontein city). The data collected from secondary sources were found to be very limited and were utilised only to check the correctness and adequacy of primary data wherever required.

The data collected from the primary household survey were checked for correctness and relevance and then compiled in code sheets. This compilation was analysed using descriptive statistics to see the variations and consistency in the responses. Besides, Cronbach α test was conducted to test the reliability of the data set.

The performance evaluation of the attributes and factors was conducted by using the data set collected through the perception survey. To evaluate the performance of the factors and attributes, a mathematical quantitative Smart Factor Index (SFI) and Smart Attribute Index (SAI) were developed, based on the weighted average method. The Smart Factor Index evaluates the performance of each factor under different city development attributes. It is defined as the function of values assigned to a factor by the respondents in a scale of -3 to +3 (-3 representing the worse performance, +3 maximum performance and zero neutral) and the total number of respondents (Das and Emuze, 2014; Giffinger, et al., 2007). The mathematical equation is presented in Equation (Eq.) 1.

$$SFI=(\sum(P*X))/(\sum X) \qquad \text{Eq.1}$$

Where: P= Values assigned to each factor by the respondents

X= Number of respondents assign a particular value

Smart Attribute Index evaluates the performance of various developmental attributes of the city. It is a function of the cumulative smart factor indices under each attribute and weightages of each factor. It is also evaluated in a scale ranging from -3 to +3. Eq. 2 presents the mathematical equation used to evaluate SAI.

$$SAI=(\sum(SFI*W))/(\sum W) \qquad \text{Eq.2}$$

Where SFI= Smart factor index

W= Weightage of each Indicator in each factor

The discussions made and information gathered from focus group discussions were analysed by narrative and interpretative analysis (Creswell, 2017; Saunders, Lewis and Thornhill, 2016).

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Development of ASA linked conceptual models

The data analyses were followed by the development of causal feedback relationships among the factors under each attribute by applying the ASA paradigm and using SD principles. Development of Causal Loop Diagrams (CLD) for the city system generally preludes conceptual modelling. Essentially CLDs are the visual, largely qualitative representation of how the analyst believes the system behaves, in respect of the interactions among those entities that matter, to resolve the problem (Beck, et al., 2018). The CLDs offer dynamic hypothesis (theory) on which the systems are believed to work or behave and identify the leverage points on which decisions can be made or policy interventions can be evolved.

In this investigation, when the CLDs were developed, cause and effect relations were properly comprehended and appropriate polarities (negative or positive) were assigned. The loops were identified as either reinforcing or balancing. A reinforcing loop forms when an increase (decrease) in a variable lead to a tendency for the variable to be increased (decreased) due to the feedback through other variables in the loop. A balancing loop forms when a variable increases (decreases), and there is a tendency for the same variable to decrease (increase) due to the feedback through other variables in the loop (Mohammadi, Tavakolan and Khosravi, 2018; Sterman, 2000). However, to develop the loops, first one-way causalities were established, and then the feedback relations were checked and established if there are any. Then the various cause and effect relationships among the factors and the feedback CLDs were combined to develop the conceptual models. The CLDs, cause and effect relationships and conceptual models were discussed with stakeholders and experts through focus group discussions to examine their correctness and logical linkages and validate the models. The models were developed following a series of iterations of development, discussion, amendment and final validation. The validated conceptual models were used to comprehend the influence of the three sectors – economy, mobility and governance, for transforming the city to a smart city.

Scenario of Bloemfontein as a Smart City: Findings and Discussion

The scenario of smart city perspectives of Bloemfontein was comprehended based on the concurrent analysis of (1) evaluation of the performance of three aspects, such as economy, mobility and governance, (2) perceptions and opinions obtained from the focus group discussions and (3) the dynamic hypotheses generated from the conceptual models developed for each of the three aspects.

Before the evaluations were conducted first the veracity of the data was checked through descriptive statistics and Cronbach α. The low standard deviation in each factor shows the consistency and high Cronbach α (> 0.9) values confirm the reliability of the data set used. The different development attribute scenarios are discussed below.

ECONOMY

Table 1 presents the current economic performance of the city. Twelve factors under five attributes were used for the evaluation. It was observed that the employment rate in knowledge-intensive sector and productivity (GDP) per employee is reasonably high and the unemployability rate is very low. Factors like self-employment rate, new businesses registered, importance as decision-making centre, proportion in part-time employment, R

& D expenditure and ICT connectivity have moderate positive indices, implying average performance. However, the performance of factors like patent applications per inhabitants, and availability of company headquarters is very poor and it seems their presence is insignificant. Consequently, it is found that economic attributes like productivity and flexibility in the labour market have a strong influence in the city, whereas it lacks international embeddedness and economic image, trademark and branding. Entrepreneurship and innovation are observed to be present but not so strong. Thus, although the economic attributes of the city indicate mixed performance, the positive influence of productivity, flexibility in the labour market, entrepreneurship and innovation offer opportunities for the economy of the city to strengthen further. The challenge is to enhance the economic image, branding and international embeddedness of the city.

In support of these findings, urban planning experts and professionals and researchers in the focus group discussions stated that:

> *"…. Bloemfontein has certain potentials for economic development because of its potential for setting up of knowledge-intensive and ICT related industries. However, entrepreneurship, creation of economic image and branding as well as innovative spirit should be strengthened."*

Similarly, the ICT experts added:

> *"…. ICT plays a very important role in enhancing seamless communication both at the national and international level. Strengthening of ICT services in the city will assist in inter-(national) connectedness and perhaps can attract investments in the emerging and advanced sectors such as ICT or knowledge industries."*

Table 1 Performance of economic attributes of Bloemfontein city

Smart factors	Mean	SD	SFI	Smart attributes	SAI
R&D expenditure	1.2	0.15	1.0	Innovative spirit	*0.51*
Employment rate in knowledge-intensive sectors	2.1	0.24	2.4		
Patent applications per inhabitant	-2.2	-0.25	-2.5		
Self-employment rate	1.3	0.15	1.2	Entrepreneurship	1.2
New businesses registered in proportion of existing companies	1.25	0.17	1.2		
Importance as decision-making centre	-1.4	-0.14	-1.5	Economic image and branding	-1.5
GDP per employed person	2.1	0.30	2.0	Productivity	2.0
Unemployment rate	2.3	0.28	2.2	Flexibility in labour market	1.75
Proportion in part-time employment	1.4	0.22	*1.3*		

Table 1 continued

Smart factors	Mean	SD	SFI	Smart attributes	SAI
Companies with HQ in the city quoted on the national stock	-2.60	0.35	*-2.75*	International embeddedness	-0.5
ICT connectivity with the companies	1.6	0.25	*1.5*		
ICT use by companies	0.5	0.10	*0.5*		
Cronbach'α					0.925

(Source: Camboim, Zawislak and Pufal, 2019; Das and Emuze, 2014; Giffinger, et al., 2007; Moussiopoulos, et, al., 2010; Praharaj and Han, 2019; Shapiro, 2008; Sokolov, et al., 2019)

Figure 1 presents a conceptual model for the economic sectors of the city. Amongst influential economic factors, entrepreneurship is considered the key factor that defines the economic performance of a city (Das, 2019; Sokolov, et al., 2019). A higher level of enterprising activities in the city would lead to enhancement of the economy (Van der Weijden, et al., 2017), which in turn would facilitate the location of corporate offices or business decision-making centres. The location of corporate offices would increase inter-(national) embeddedness enhancing both communication and business relations, which would have a positive influence on the enterprises located in the city as shown by the reinforced causal feedback mechanism ER1. Besides, entrepreneurship would bring in innovation (Van der Weijden, et al., 2017), which would positively influence productivity in the city. Higher productivity would enhance the economic image and branding of the city creating a congenial environment for entrepreneurship development as feedback through a mechanism presented the reinforcement loop ER2. Thus, entrepreneurship in the city is strengthened by both the mechanisms represented by reinforcing loops ER1 and ER2. Further enhancement of entrepreneurial activities in the city with the aid of innovation would lead to higher productivity and GDP per employee (Sokolov, et al., 2019; Van der Weijden, et al., 2017). Higher productivity, income, innovation and entrepreneurship would enable the city as an important decision-making centre for business, which would transform the economy to a smart economy (Kummitha, 2019) as seen through feedback mechanism ER3.

Thus, enhancement of entrepreneurship in the city remains vital for transforming the economy to a smart economy, which can contribute to transforming the city to a smart city. This can be enhanced by inculcating innovation, increasing productivity and creating an economic image. Concurrently, there is a need for efforts to increase inter(national) embeddedness (by use of ICT), providing incentives for setting up of corporate offices and developing it as a decision-making centre for business and enterprises. Although the self-employment rate and labour market flexibility offer a congenial environment to enhance entrepreneurship at the local level, the registration of new business needs encouragement. ICT use by companies needs augmentation, and expenditure in R & D and intensified applications for patent registration are other key areas.

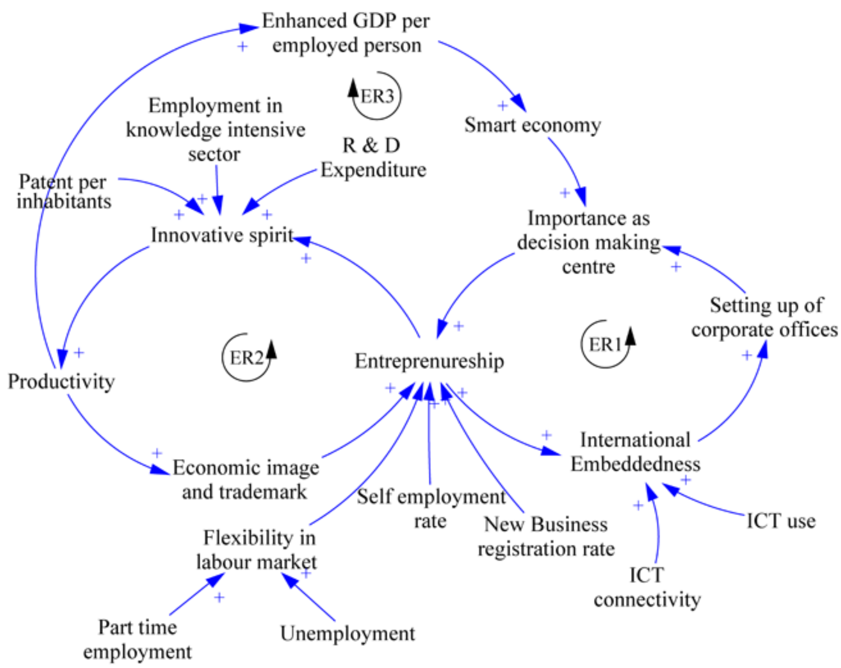

Figure 1 Conceptual models for a smart economy

MOBILITY

The mobility of the city was evaluated based on ten factors and four attributes. Table 2 presents the index values and performance of these mobility factors and attributes. The findings revealed that six factors: transport network per inhabitant, access to public transport, quality of public transport, green mobility share, use of economical cars and air transport of freight have moderate to high negative values. This implies that the performances of these factors are very poor. On the other hand, air transport for international passengers, local air transport for local people, traffic safety, and availability of computers (including mobile devices such as tablets, iPads, cell phones) in households have moderate to relatively high positive indices, although internet access in households has a low index value, indicating moderate positive performance of these factors. Consequently, the state of two of the four mobility attributes, such as local accessibility and sustainable, innovative and safe transport systems are very poor. However, the state of attributes like (Inter-)national accessibility (physical movement) and availability of ICT infrastructure for accessing travel-related information in households are encouraging. Sustainable, innovative and efficient physical movement in the city is a challenge, however, international accessibility and ICT availability in the households offer opportunities for the development of smart mobility in the city. These findings were more or less corroborated in the focus group discussions. In this context, according to urban planning professionals, academics, NGO representatives, and some of the common people:

> *"…Local accessibility in the city is a big challenge particularly with regards to public transportation. Most people rely on the use of the individual or private cars and whatever public transportation system available is not efficient…. The transportation system is neither sustainable, innovative nor safe. This is one area which should be taken up on priority if [we] look to make the city smart."*

Further, according to ICT professionals, NGO representatives, researchers and common people:

> *"… the city has good levels of internet connectivity. People use mobile devices for their travel needs (…) specifically use of GPS to select routes and access different destinations effectively. ICT can also help to work from home or anywhere, and make other social activities such as shopping by using online platforms, which can reduce the travel needs.… [we] think this is the way to go to reduce pressure on the transportation system. Perhaps this can help in developing smart mobility in the city."*

Table 2 Performance of mobility attributes of Bloemfontein city

Smart factors	Mean	SD	SFI	Smart attributes	SAI
Public transport network per inhabitant	-1.35	0.18	-1.5	Local accessibility Public transport	-1.68
Access to public transport	-1.40	0.22	-1.5		
Quality of public transport	2.20	0.35	-2.0		
Air transport (local)	1.30	0.15	1.10		
Air transport of passengers (international)	1.60	0.15	1.50	(Inter)national accessibility (physical movement)	1.11
Air transport of freight	1.10	0.12	-1.30		
Green mobility share	-1.90	0.28	-2.0	Sustainable, innovative and safe transport systems	-0.45
Traffic safety	1.40	0.20	1.50		
Use of economical cars	-1.25	0.15	-1.5		
Computers (including mobile communication devices) in households	1.80	0.22	2.0	Availability of ICT-infrastructure Computers (including mobile devices) in households	1.25
Internet access in households	0.60	0.08	0.50		
Cronbach'α					0.911

(Source: Das and Emuze, 2014, Emuze and Das, 2015; Giffinger, et al., 2007; Praharaj and Han, 2019; Sokolov, et al., 2019)

Figure 2 depicts the conceptual model for the development of smart mobility in the city. The mobility sector has been categorized into two significant elements: physical movement and access through ICT at both the local and inter-(national) level. The development of smart mobility is envisaged to be based on four major reinforcing causal feedback mechanisms involving: (1) sustainable, innovative and transportation system, (2) local accessibility, (3) availability of ICT infrastructure and international accessibility and (4) availability in ICT infrastructure leading to a reduction in local transportation needs (Emuze and Das, 2015; Kirkey, Maloney and Noelting 2017; Sokolov, et al., 2019).

A sustainable, innovative and safe transportation system is actuated using economical cars, green mobility and traffic safety at the local level (Emuze and Das, 2015). A sustainable, innovative and safe transportation system and effective local accessibility have a feedback relationship with enhanced and efficient mobility (MR1). Simultaneously, the availability of ICT infrastructure and international accessibility by air transportation system reinforce international accessibility and consequently enhances the mobility of the city through a feedback mechanism (MR2). Thus, current mobility scenarios can be transformed to smart mobility through the reinforcing effect of both the mechanisms MR1 and MR2. However, local accessibility is a major component of smart mobility. So, enhancement of the public transportation network, improvement in the public transportation system and higher access to public transportation would facilitate physical local accessibility through a feedback mechanism, MR3, improving mobility in the city. In turn, such a mechanism would also reinforce the mechanism developed by mechanism MR1 resulting in the strengthening of the sustainable, innovative and safe transportation system in the city. Further, the availability of ICT infrastructure and its higher use by households would lead to a reduction in local transportation needs. Reduction of local transportation needs would have two significant impacts- increase in traffic safety and low carbon emissions, which consequently would lead to the sustainable and innovative transportation system and smart mobility through causal feedback mechanisms MR4A and MR4B. Therefore, feedback mechanisms MR4A and MR4B along with MR3 reinforce the feedback mechanism MR1 and MR2 and result in smart mobility in the city.

The reinforcement of the ICT infrastructure would assist in reducing travel needs at the local level, thereby easing the pressure on the mobility system and increasing international accessibility. Moreover, the use of public transportation and a reduction in travel needs also reduce carbon emissions. Thus, the combination of these factors engenders smart mobility, which essentially contributes to making the smart city.

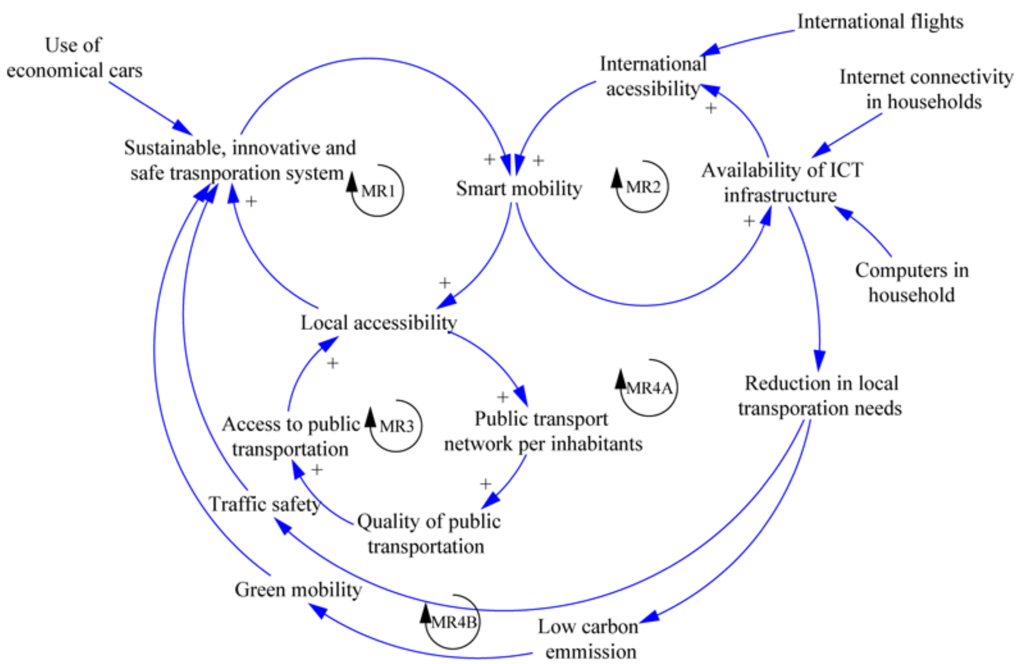

Figure 2 Conceptual model for smart mobility

GOVERNANCE

Table 3 presents the performance of the governance system of the city, which was assessed based on ten governance factors and three attributes. Four of the ten factors – city representative per resident, female city representatives in the city council, expenditure of municipality per resident, and perception of the quality of schools have relatively high positive indicators. Three factors: perception of transparency of bureaucracy, perception of fighting against corruption and participation in voluntary and social work have moderately positive indices. The moderate to high positive indices imply that the city governance system is performing reasonably well in these areas. However, three indicators, such as political activities of inhabitants, importance of politics for inhabitants and children in daycare have moderate negative indices suggesting the poor performance in these areas. It is seen, though, that the governance system is performing reasonably well in all its three attributes, such as, in creating a transparent governance system, participation in voluntary work and participation of people in decision making. The positive performance of the governance attributes provides definite opportunities for developing a smart governance system in the city. The findings from the focus group discussions supported these findings. For instance, according to a majority of the focus group participants:

> *"…. the local governance system and various departments sometimes look to be proactive and encourage the participation of different stakeholders through discussions and 'indabas' (community participation or conferences of stakeholders). They make efforts to focus on social and public services as well as to provide better service delivery. However, there are challenges with regards to inclusivity (…) as a lack of interest of the people in the development and municipal activities is a barrier against participation and inclusivity."*

Some of the other respondents added:

> *"…the municipality makes efforts to be transparent in decision making and implementation of the policies and projects to a certain extent, for example, they make the plans and programmes pubic, have customer care system, etc.…. but there are many challenges-providing timely information, lack of professionalism, etc., which need to be improved significantly."*

Table 3 Performance of governance attributes of Bloemfontein city

Smart factors	Mean	SD	SFI	Smart attributes	SAI
City representatives	2.4	0.25	2.5	Participation in decision-making	0.75
Political activity of inhabitants	-1.35	-0.15	-1.5		
Importance of politics for inhabitants	-1.45	-0.17	-1.5		
Female city representatives	2.1	0.25	2.0		
Expenditure of the municipal per suburbs	1.8	0.30	2.0	Public and social services	1.025
Children in day care	-1.4	-0.15	-1.2		
Perception of quality of schools	2.2	0.28	2.0		
Participation in voluntary works	1.2	0.15	1.3		

Table 3 continued

Smart factors	Mean	SD	SFI	Smart attributes	SAI
Perception on transparency of bureaucracy	1.4	0.20	1.5	Transparent governance	1.5
Perception on fight against corruption	1.4	0.18	1.5		
Cronbach'α					0.914

(Camboim, Zawislak and Pufal, 2019; Coe, Paquet, and Roy, 2001; Das and Emuze, 2014; Giffinger, et al., 2007; Marsal-Llacuna, 2016; Moussiopoulos, et, al., 2010; Praharaj and Han, 2019; Shapiro 2008; Sokolov, et al., 2019)

The conceptual model for smart governance system in the city is presented in Figure 3. People's involvement in decision-making processes is the most important attribute in the governance system (Das and Emuze, 2020). People's participation in decision making and governance would lead to transparency in governance. Transparency in governance is influenced by transparency in bureaucracy and perceptions of fighting corruption. A transparent government would encourage higher expenditure, participation in public and social services like children daycare, quality schools and civic services in the suburbs of the city. The whole process of participation, transparency in governance, and public and social services strengthens the governance of the city (Branagh and Ratcliffe, 2002; Guimaraes, et al., 2020; Hunt and Rogers, 2016) through a feedback mechanism (GR1). Similarly, participation in decision making would positively influence political activities of inhabitants and provide opportunities for adequate city representatives including female representatives in the governance system, thereby reinforcing participation in decision making through reinforcing feedback mechanism (GR2). This mechanism, in turn, reinforces the mechanism GR1; as a result, the governance system developed is also further strengthened. Besides, as the governance system gets strengthened, it would enhance the importance of politics for the people resulting in higher political activities by them. The combination of these attributes and their reinforcing effects through feedback mechanisms ultimately create an environment for smart governance (GR2A).

Thus, the smart governance system relies on transparency in governance and participation of people or stakeholders in decision-making, which is considered an essential precursor to smart city development. Although Bloemfontein city offers positive indications on these attributes, there is a need for further strengthening. The democratic setup and adequate local governance system provide an opportunity for the development of a smart governance system in the city if policy interventions are made to make people politically active; create an environment to involve people in social and political activities by encouraging participation in voluntary work and child care; making an equitable expenditure in suburban areas; and, more importantly, allowing them to be a part of the decision making processes and building transparent bureaucracy.

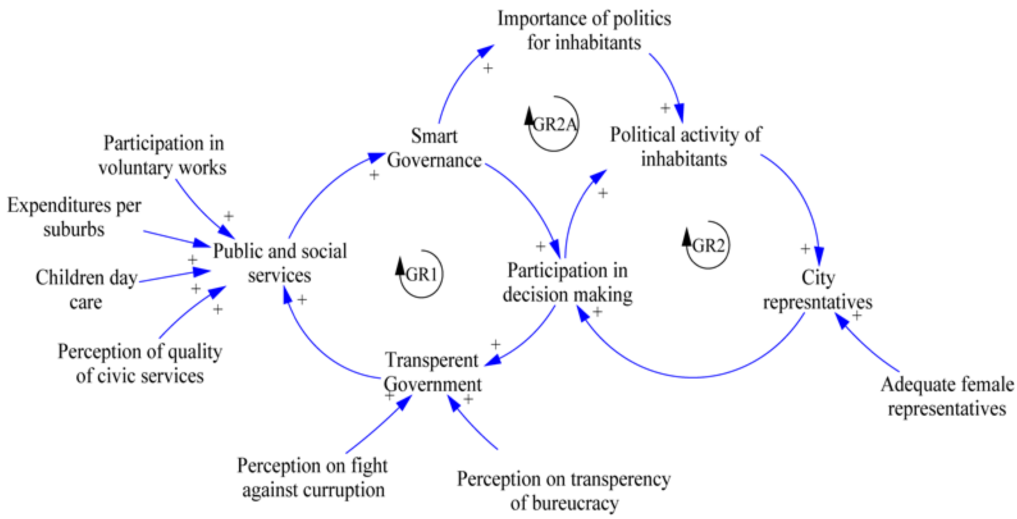

Figure 3 Conceptual model for smart governance

Conclusion

A smart city is regarded as a well-performing city in one or more of its attributes, based on the potentials and challenges it offers. Some of the important aspects include economy, mobility, governance, people, environment, ICT, etc. Moreover, the purpose of developing smart cities is to enhance the capacity of the city and judicious resource management for optimal development of the cities. In recent times, the development of smart cities both in developed and developing countries has gained momentum.

An evaluation of the smart city perspectives of South African cities was conducted by considering Bloemfontein as a case study. In this context, this investigation first provides an evaluation of the performance of the important influential factors and attributes under three important aspects: economy, mobility and governance system. Secondly, the perspectives of different stakeholders were sought through focus group discussions. This provided ASA premised conceptual models based on the analytical causal feedback logics among the factors and attributes in these aspects, which are aimed at enabling the development of policy interventions for transforming it to a smart city.

The evaluation suggested that there are positive indications in all three aspects but there are serious challenges to be met, particularly in the economy and mobility sectors. The positive attributes of governance scenarios offer certain opportunities. Also, the process of rigorously extracting causal feedback mechanisms among the factors and attributes in each sector brought the influential inter-linkages and mechanisms to light. Entrepreneurship is found to be vital for engendering a smart economy, which needs to be reinforced through the inculcation of innovation and increasing productivity. Moreover, it is necessary to explore the establishment of knowledge or ICT based industries and steps to improve the economic image, branding and international embeddedness. In other words, policy interventions to reinforce the causal feedback relationship among entrepreneurship, innovation, productivity, economic image and international embeddedness, would foster a smart economy.

Similarly, local accessibility, and sustainable, innovative and safe physical movement in the city are major concerns. Strengthening of public transportation to provide efficient local accessibility and advancement of ICT to ensure an innovative, sustainable and safe transportation system, as well as to reduce the travel needs and consequently the pressure on the transportation system, would result in smart mobility.

Further, it is essential to ensure effective participation of stakeholders in the decision-making process alongside the elected city council, and transparency in governance. The complementary effect of the combined attainment of the three attributes of would enable the transformation of the city to a smart city.

The development of smart cities is a complex problem and needs adequate and appropriate policy interventions. However, evolving policy interventions poses specific modelling challenges that include interdependency, inter-linkage and causal relationships among the various parameters that influence the smart city development. These challenges are compounded by the lack of adequate and reliable data, uncertainties, the role of stakeholders, and other prominent aspects that are not easily amenable to quantification. In this context, the study has two significant contributions. First, it offers the perceptions of the people on the performance of the factors that influence the economy, mobility and governance and what needs to be reinforced to make the city smart. This, in turn, provides an avenue for an inclusive and bottom-up approach of smart city development. Second, ASA linked conceptual models with their integrative nature are found to provide a framework to elicit the complex and dynamic inter-linkages among various factors and attributes under the three concerned aspects, based on which policies can be generated to augment the strengths and alleviate the weaknesses in an urban system (city) to facilitate the development of smart cities. This could help the policy and decision-makers to make scenario analysis and take appropriate policy decisions.

However, there is also a need to transform these conceptual models to computer simulation models, which would reveal the gaps between the desired condition and current scenario, and the extent to which various attributes need enhancement, and that is the next goal of this investigation. Despite the limitations of the study being premised upon the perceptions of people and stakeholders, it offers a way forward conceptually to guide the policy makers and planners for possible action for transforming Bloemfontein city or similar cities in South Africa to smart cities.

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