MANAGING URBAN INFRASTRUCTURE TRANSITIONS FOR SMART SUSTAINABLE CITIES

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ABSTRACT

Traditionally, the development and management of urban subsystems were seen as a basic engineering and administrative task. The infrastructural system approaches developed throughout the 20th century are no longer adequate to effectively address the current and future challenges that face cities. The concept of a smart sustainable city has emerged as a new urban development ideal with the aim of integrating the smart city and sustainable city paradigms, as smart city capabilities can be incorporated as a leverage to achieve the sustainability goals of the city. The nature of the existing literature related to smart sustainable city transitioning is investigated in a literature review. It is seen that there is a need for the development of a holistic framework for smart sustainable cities to guide and assist city planners, urban governance structures and policy makers to plan, manage and implement purposeful and effective urban transitions. Within the existing literature there is an absence of such a framework as a holistic guideline to address the uncertainties surrounding the real-world implementation of smart sustainable cities. From literature it is becoming clear that systems thinking provides a meaningful perspective from which to understand the dynamics of cities and urban change. Transitioning existing cities to become smart sustainable cities would require adaptation of the infrastructure networks that guide the functioning of the city and thus provide a meaningful point of intervention. The literature review and the planned work that build upon it forms an important contribution to the understanding, implementation and policy design of smart sustainable cities.

Key words: Smart sustainable cities, smart cities, sustainable cities, urban infrastructure, infrastructure transitioning, multi-project, urban systems, complex systems thinking, review.

INTRODUCTION

Sustainable development is based on the three principles of sustainability: environmental, economic and social sustainability (Perlman and Sheehan, 2007). The term 'sustainable development' was first defined as "development that meets the needs of the present without compromising the ability of the future generations to meet their own needs" (Brundtland, 1987). From the principles of sustainable development and escalating urbanisation challenges, the concept of sustainable cities emerged (Perlman and Sheehan, 2007).

Information and communication technologies (ICT) come in many forms (services, infrastructures, data analytics capabilities, and applications) and are increasingly seen to supply surpassing ways to solve a range of complex environmental challenges and emerging socio-economic concerns currently

facing cities. In many parts of the world ICT approaches are already enabling cities to remain sustainable and liveable for citizens (Bibri and Krogstie, 2017). Smart initiatives can be used to support and advance environmental sustainability (Kramers *et al.,* 2014).

Smart cities hold great potential for advancing sustainability, despite their current implementation often lacking sustainability considerations (UN-DESA, 2015). An interconnectedness exists between the goals of smart and sustainable cities and an opportunity to incorporate both smart and sustainable city approaches. This could draw upon their multiple benefits and abilities to complement and compensate each other's shortcomings (Ahvenniemi *et al.,* 2017; Bifulco *et al.,* 2016). Cities can strive towards this insight by embracing both smart approaches and sustainable development (Geldenhuys et al., 2018).

A smart sustainable city is an integration of both smart-and sustainable city concepts. A smart sustainable city can be defined as a city that (Höjer and Wangel, 2015):

i. meets the needs of its current population,
ii. avoids negatively impacting the ability of future generations or other people to meet their needs, thereby not exceeding the local or global environmental limitations, and
iii. incorporates ICT technologies.

There is a need to develop a holistic approach to guide the transitioning of existing cities to become a smart sustainable city. In this paper a systematic literature review is presented where important literature is sifted and short-listed to better understand and refine the knowledge gap to be addressed.

A literature review is presented to guide understanding of the research gap and identify the most applicable body of knowledge. The identification and selection of research is described in the "Approach" section, and the analysis results explored under "Nature of existing research". Thereafter the main observations are presented and their relevance to the research problem explained in the "Discussion" section, followed by a summary of the conclusions of the paper.

APPROACH

The literature review will focus on the main research question: How can the process to transition a city to become a smart sustainable city be planned, implemented and managed? A systematic review helps to ensure that all appropriate literature relating to the transitioning of cities to smart sustainable cities form part of the literature selection.

Searching and Identification

Various databases were used for finding research papers: Compendex (Engineering Village), Elsevier, Emerald, Google Scholar, IEEE Electronic library, Science Direct, Scopus, Taylor and Francis Journals, Wiley and WorldCat. In Figure 1 the identification stage consists of three independent search queries: n1, n2 and n3 with their results updated in January 2020. From multiple search attempts over a period of two years these searches in Figure 1 proved to deliver the most relevant literature with regards to the research problem. Each of the queries, n1 to n3, delivered 58, 180 and 264 results respectively. These results were inspected by hand for duplicates and retracted articles and thereafter were screened by title and abstract for relevance to the research topic. This delivered 100 articles that were

regarded as very relevant and 112 articles that were regarded as good secondary literature. During the second screening of the relevant literature, only articles in English were included and books and chapters excluded to deliver a total of 90 papers. During the eligibility phase only 76 papers were available in full text. From the twelve unavailable papers the only one that was directly related to smart sustainable cities was in Agrawal (2017). Agrawal (2017) focused on a law and policy approach by studying Indian judiciary to help secure the rights of pedestrians for smart sustainable cities. During the next step in the eligibility phase papers were screened by their full text to verify their relevancy to the research questions and leaving 35 relevant papers. While inspecting the papers the snowballing technique was also used as means to gain more literature. The snowballing technique entails discovering relevant literature that have cited or have been cited by a selected paper or by following up on a relevant source of publication to look for other possible papers. The papers identified with the snowballing technique were also screened in full text and delivered another 3 papers that were included to obtain a list of 38 papers.

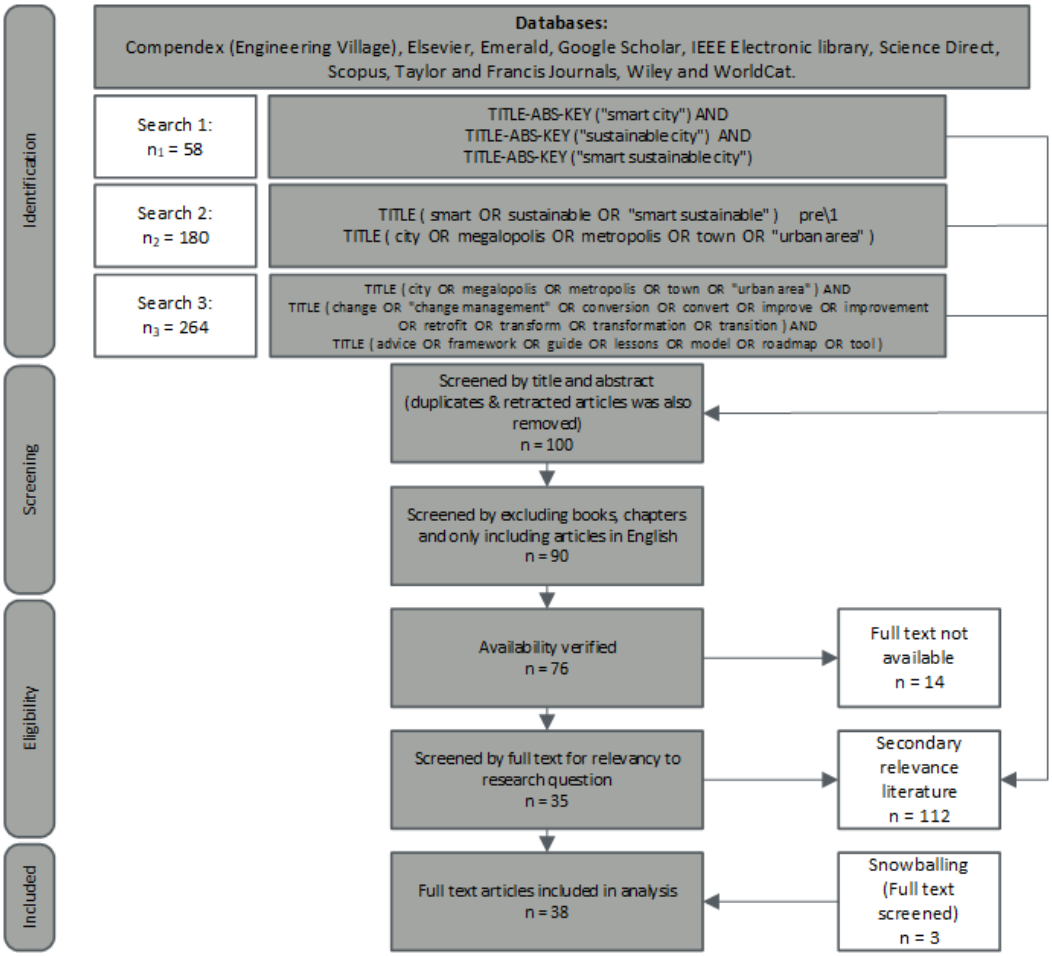

Figure 1: Systematic search process.

NATURE OF EXISTING RESEARCH

The thirty-eight papers that were identified in Figure 1 are the most relevant to the research problem. The broad characteristics of the literature selection were investigated to understand the composition and type of content available to address the research problem.

Geographic analysis

Geographic attributes of the literature are presented in Figure 2 and Figure 3 showing the geographic area that was focused on by the studies in the literature selection and the authors' country of affiliation respectively.

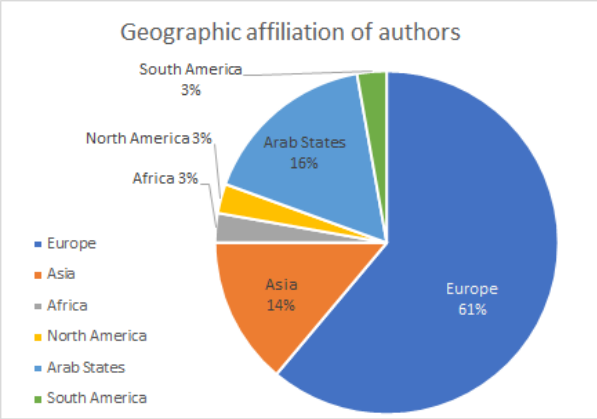

Figure 2: Geographic affiliation of academic authors grouped under the world regions.

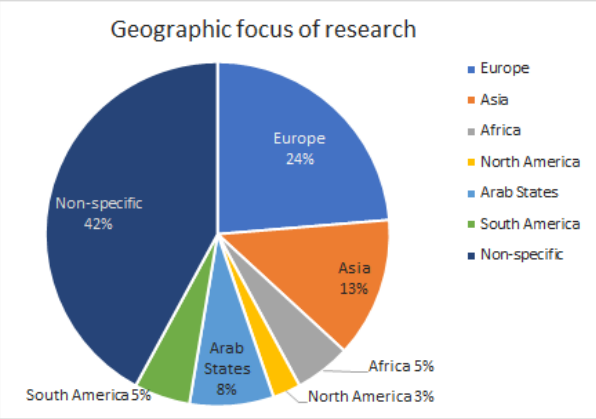

Figure 3: Geographic focus of the selected studies grouped under the world regions.

In Figure 2 it is observed that almost two thirds of the authors that produced the selected papers are affiliated with European universities and institutions. Researchers in the United Kingdom, Norway, Sweden and the Netherlands make up the most prominent part of the representation. Other European countries represented include Finland, Germany, Switzerland, Italy, Portugal, Spain, Serbia, Latvia, Slovakia and Hungary. Asian affiliation constitutes fourteen per cent of the research with contributors from Japan, Indonesia, Taiwan and India including Russia. Sixteen per cent of the research is from the Arab states Lebanon, with the involvement of a co-author in the United Kingdom (UK), as well as researchers from Egypt, Saudi Arabia and Bahrain. One Egyptian affiliate collaborated with Norway to identify failure and success factors from smart city and sustainable city examples in the United Arab Emirates (UAE), China and South Korea. South America, North America and Africa each have the smallest representations at three per cent. A Brazilian study focused on smart sustainable city residence satisfaction evaluation, the North American study on smart sustainable city infrastructure resilience and the South African research on general urban transitioning from a complex adaptive systems perspective.

There is a slight correlation between the compositions of geographic affiliation of the researchers and geographic focus of the papers shown in Figure 3. However, forty-two per cent of the research do not focus on any specific country, rather on definitions, concepts, generic models, tools and frameworks related to smart sustainable cities. The rest of the literature comprised of studies that incorporated data, case studies and surveys from existing cities to investigate hypotheses, identify trends and drivers, challenges, success factors, to build theory and in some cases with the intent to reflect on past projects, evaluate current interventions and inform future planned projects. Almost a quarter of the studies relate to Europe, focussing on the UK, Netherlands, Norway, Sweden, Italy, Germany, Spain, Serbia, Romania, Latvia, Slovakia and most often Europe in general. Thirteen per cent of the studies looked to Asia (Japan, Indonesia, Taiwan, South Korea, China and India), eight per cent to Arab States

(Egypt, UAE and Saudi Arabia) and five per cent to both Africa (South Africa and Tanzania) and South America (Brazil). Only three per cent of the research focussed on North America.

Publication timeline

Literature of both primary relevance (38 papers) and secondary relevance (112 papers), as well as the summed total are plotted on the research publication timeline in Figure 4. The timeline stretches until 2019 and was updated in January 2020. Secondary literature is regarded as literature that in some way digress from the research direction, but can contribute towards building the transition framework or understanding parts of the project. An exponential like growth rate can be observed in all three trend lines in Figure 4, but a decline in secondary literature was observed for 2019. Knowledge useful to smart sustainable city transitions is very fragmented. In 2019 a slight shift in fragmented knowledge towards smart sustainable specific literature can be observed. This growth, especially in the primary literature, indicates an increasing interest in and around the field of smart sustainable cities.

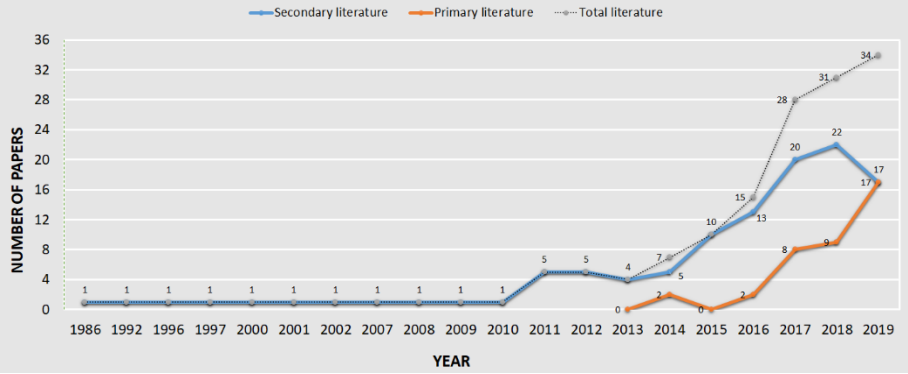

Figure 4: Publications per year for primary, secondary and total relevant research up to Jan 2020.

Organisations conducting research

Figure 5 presents the organisations involved in conducting research of the final literature selection. More than three quarters of the identified research was conducted through universities, thirteen per cent by public research institutions, five per cent by private companies (specialising in ICT) and three per cent by consulting firms.

Research funding

Seventeen per cent of studies were funded by the European Union, as in Figure 6, and orientated towards informing current projects, policy and the Horison 2020 Smart Cities and Communities (H2020 SCC) initiative. Eleven per cent of the studies were without funding, another three per cent funded by the Toyota Foundation from the private sector, and three per cent by government at city-level in Indonesia with future plans to transform the Yogyakarta city to a smart sustainable city.

Research drivers and aims

Indonesia, Sweden, Serbia and Saudi Arabia form eighteen per cent of the total research that have future urban transformation projects as a driver behind their research, indicated in Figure 7. Eight per cent of the identified research are concerned with current projects underway, the main intent being evaluation of progress and status with regards to smart sustainable city dimensions. These studies focus on developing and refining indicator-based approaches for this purpose. Work done on existing

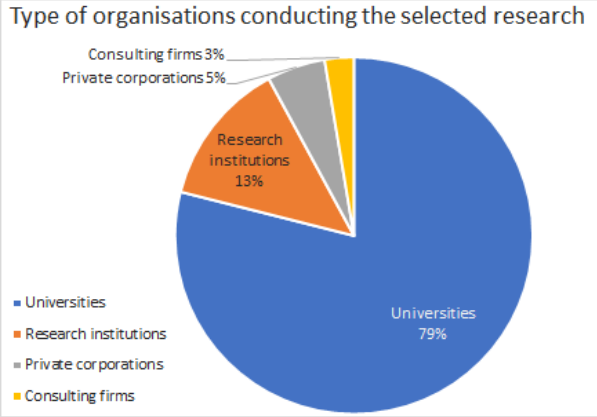

Figure 5: Organisations involved.

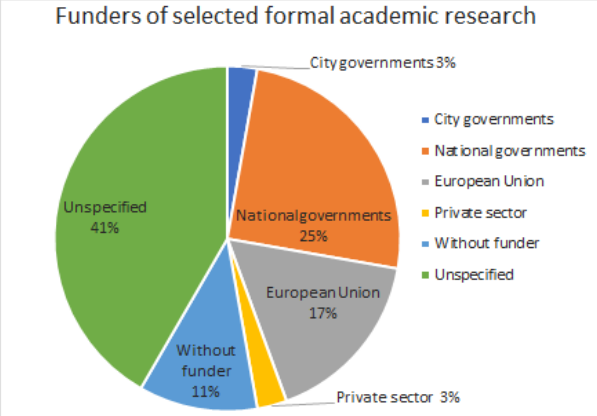

Figure 6: The funding sources.

cities also make up another ten per cent of the total and are focussed on observing and learning from existing cities as examples and sources of information useful for conceptualisation and evaluation research. Sixteen per cent of the research have an analytic intent and are predominantly big data and ICT orientated. Another study specifically concerned with energy planning in smart sustainable cities is also of an analytical nature. The largest driver behind almost half of the research is to inform policy and agenda at local and international level. This mainly entails developing indicators to promote measurability, standardisation and target setting, as well as identifying challenges, barriers and possible interventions requiring future research.

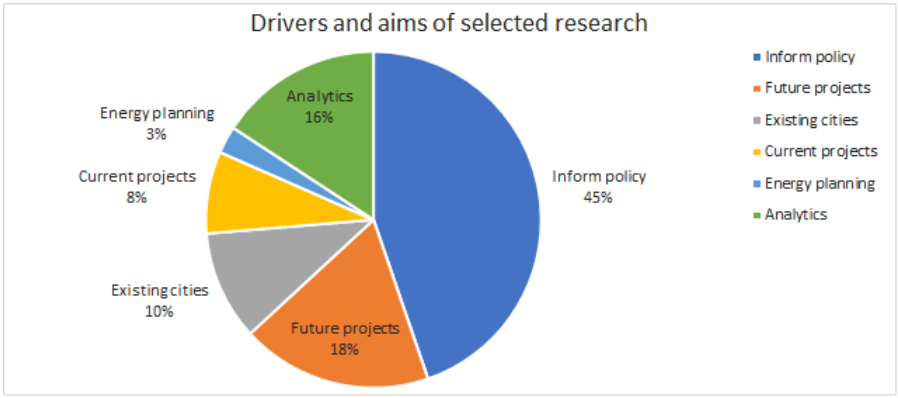

Figure 7: The grouped drivers and aims behind the selected research papers.

Subject fields

In Figure 8 a grouping of the main subject fields involved in the research papers selected for the study is summarised. A ratio of thirty-seven per cent and thirty-four per cent respectively for an urban studies perspective and information and communication technologies (ICT) can be observed. Urban studies are not a development focused on a single science, but focuss on the cross-cutting involvement covering multiple disciplines (Acuto *et al.,* 2018).

The literature grouped under ICT include big data analysis, information management, communication networks within smart cities, IOT (internet of things) and sensor-based applications. These ICT studies are generally conducted by researchers with a computer science background and focus on smart cities, and recently a slight shift in research has emerged towards smart sustainable cities.

Ten per cent of the literature have a sustainability focus, which entails establishing a balance between the three dimensions of sustainability, (namely economic, environmental and social impact) and shares a close relation to urban studies. The sustainability literature addresses the evaluation and transitioning of cities to become more sustainable and inform policy to mitigate climate change.

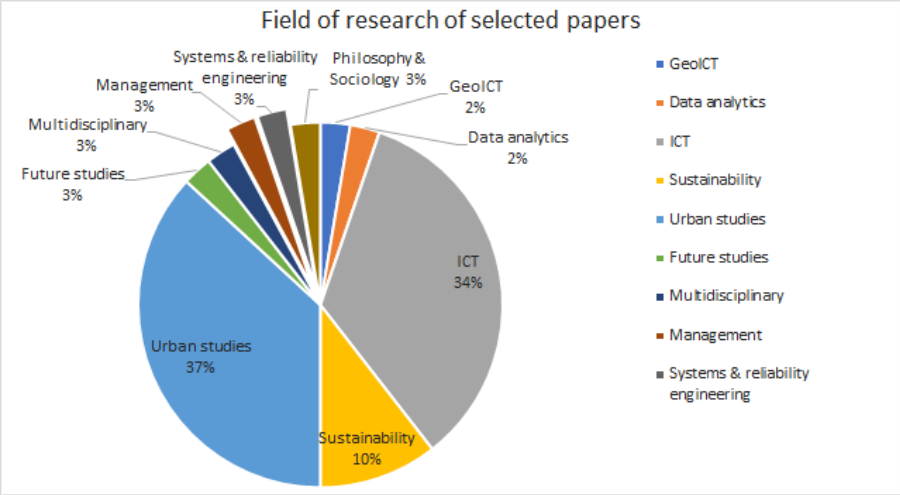

Figure 8: Subject fields represented in the selection of research papers.

Data analytics and geographic information and communication technologies (GeoICT) each make up equal portions of two per cent of the total research. Philosophy and sociology, systems and reliability engineering, management, multidisciplinary and future studies each make up three per cent of the total research. Literature on data analytics focused on rigorous mathematical relationships and optimisation approaches for smart cities. GeoICT literature focused on the purposeful implementation and exploitation of ICT systems and sensors that unite the spatial dimension (geographical layer) and informational dimension. GeoICT and data analytics are fields that closely relate to ICT. Philosophy and sociology research investigated the ethics and consequences of digitisation and smart city changes on society. The multidisciplinary research entails decision making and important considerations for smart sustainable city development. The future studies research entails anticipating and understanding the future of smart sustainable cities.

Management research has thus far investigated smart city and sustainable city projects from a strategic perspective to determine significant success and failure factors that could inform policy design. Systems and reliability engineering focused on understanding the city as a system-of-systems (SoS) and decomposing its sub-systems hereby reducing problem complexity in order to provide effective engineering solutions. It is noted that there is a scarcity of research that informs smart sustainable city development from a management and systems perspective, which plays an important role in the development and transformation of a city (Höjer and Wangel, 2015).

Areas of contribution

Figure 9 shows the focus and contributions present in the literature selection. The type and composition of content available in the literature selection surrounding the research question is as follows:

i. Conceptualisation (38%): There is still ongoing exploration and debate regarding, for example, smart sustainable city (SSC) conceptualisation. General topics include definitions,

characteristics, components, challenges and lessons drawn from existing city examples. It is observed that theoretical perspectives such as complex systems thinking and the multi-level perspective (MLP) are gently intertwined within the research material but not formally explored.

ii. Evaluation (28%): Attempts to develop performance metrics and assessment tools to measure city status, performance and progress with regards to smart, sustainable and smart sustainable city dimensions or comparison with other cities. These topics mostly entail creating and comparing indicators, benchmarking, indexing and ranking systems.

iii. Actualisation (22%): This research is concerned with determining best practice methodology and the planning, design, implementation, coordination, management and governance of real-world systems and projects such as cities, infrastructure and transitions from a practical perspective. There are very few actualisation papers written for smart sustainable cities. Those included address computer science related aspects such as big data, ICT networks and information management (Bibri and Krogstie, 2018), smart transport management (Dinh Dung and Rohacs, 2019) a stakeholder engagement model (Ibrahim *et al.,* 2017), citizen engagement insights (Teremranova and Mutule, 2019), a visions development model (Bibri and Krogstie, 2019a,b,c), and an urban transformation readiness roadmap (Ibrahim *et al.,* 2018). A climate change framework for urban transitioning (Göpfert *et al.,* 2019) is included to enrich the knowledge pool regarding the possible means for implementation and actualisation of the new smart sustainable urban concept.

iv. Analytics (9%): Papers focussed on data processing and analysis for smart sustainable cities. Examples include big data and ICT information management frameworks, qualitative methods and optimisation models, risk and resilience analysis for infrastructure and energy planning.

v. Development of tools and aids (3%): This category refers to specialised and practically implementable tools and technology solutions for smart sustainable city applications. Current tools related to smart and sustainable city solutions and applications are continually evolving as technological capabilities advance and diverse solutions emerge from bottom-up development.

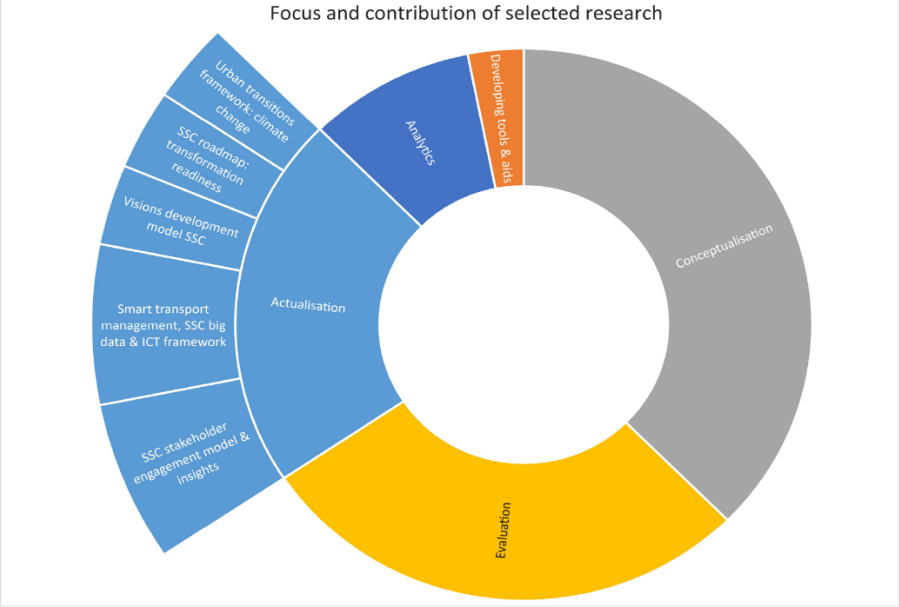

Figure 9: The focus and contribution of the selected research papers.

A broad sense regarding the structure and progression of knowledge available surrounding smart sustainable city development is conveyed in Figure 9. The first observation is the prominence of the conceptualisation portion indicating that most literature available are focused on defining and understanding the main concepts, foundational aspects and supporting knowledge for smart sustainable cities and its relation to its respective smart and sustainable predecessors. The second largest portion represent the studies that strive to determine how cities should be the evaluated and monitored with regards to the recently established smart sustainable cities ideal. This is followed by studies concerned with practices and guides for the real-world actualisation and implementation of urban agenda. Thus far there is a deficit of a holistic framework for smart sustainable city transitioning. Analytics will determine how the data will be processed and utilised to provide structured information. The development of sophisticated tools and aids will ultimately depend on availability and usability of city information.

This progression of knowledge presented in Figure 9 corresponds to the main avenues of research for smart sustainable cities discussed by Bibri and Krogstie (2017), namely theoretical grounding, urban evaluation, translation into built environment and infrastructure, hereby enabling advanced analytical capabilities of the city and subsequently the development of innovative solutions and approaches.

Paper deliverables

The main deliverable presented by each item of literature is grouped under specific types as illustrated in Figure 10. They are as follows:

i. Dimensions and characteristics (3%): This entails recognition of the main dimensions of a smart sustainable city and its sub-systems in order to understand the various domains at stake. The literature in this grouping had this as their main output or contribution.
ii. Indicators (12%): These studies investigate and compare various existing indicator standards for smart cities and sustainable cities in an attempt to develop an appropriate and holistic indicator standard for smart sustainable cities.
iii. Index (3%): Bhattacharya et al. (2018) combined multiple indicators, which capture various characteristics in the environmental, economic, social, cultural and lifestyle dimensions of the city, to determine a single performance value or index. The Smart Sustainable Cities Development Index (SSCDI) is aimed to assess, guide and compare the performance and progression of development between smart cities in India as part of their national milestones.
iv. Ranking (3%): The ability to benchmark and rank cities can enable policy makers to identify areas of improvement and strengths that can be leveraged to become more smart and sustainable. The research by Akande et al. (2019) developed a system for ranking twenty-eight European capital cities according to how smart and sustainable they are. The results revealed various anomalies and trends that are insightful.
v. Review (9%): These studies presented literature reviews regarding the origins, foundational concepts and components of smart sustainable cities as an urban practice. One study also presented five tensions between the visions and policies of smart cities and sustainable urban development goals.
vi. Insight (24%): These papers mainly focus on gaining understanding and building new knowledge. One example is the study by Aina (2017) which compared frameworks and case studies in literature to gain lessons and determine policy implications of using GeoICT for

smart city development in Saudi Arabia. Elgazzar and El-Gazzar (2017) identified success and failure factors of smart and sustainable city projects by analysing five existing smart and/or sustainable city examples.

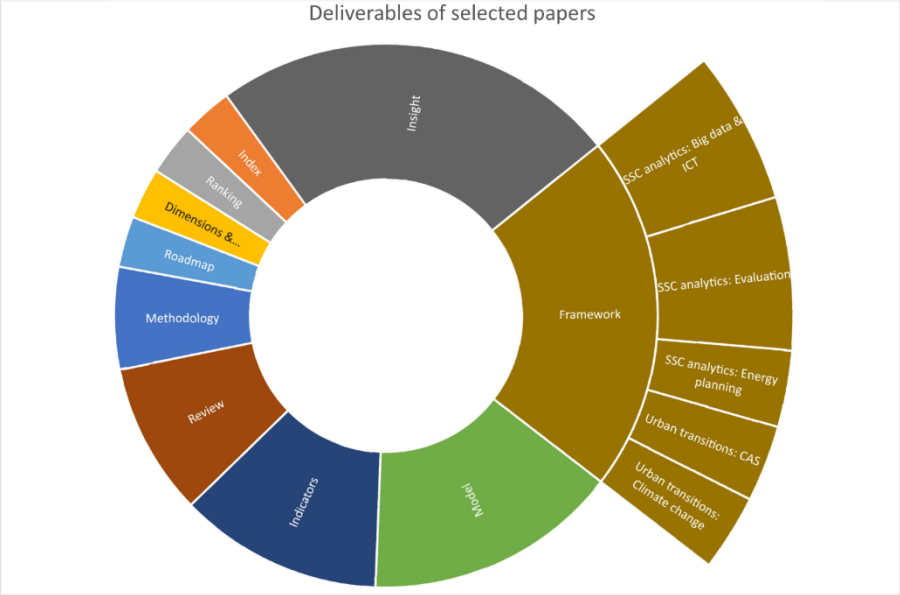

Figure 10: The deliverables developed in conjunction to the selected research papers.

vii. Model (15%): Models are representations to provide understanding regarding the structure, functioning and dynamics of certain concepts, but do not provide instructions or guidance. They are conceptual in nature and can play a supportive role to a framework or roadmap.

viii. Methodology (6%): Methodology entails detailed approaches for specific applications. Timashev (2017) proposed a methodology for urban risk management of critical infrastructures based upon the concept of a quantitative resilience factor. This approach can be useful to decision making at a municipal level.

ix. Roadmap (3%): Ibrahim et al. (2018) presents a smart sustainable city transformation roadmap focused on the transformation readiness of a city. A roadmap provides the general vision, direction and high-level goals and priorities of the transformation process towards becoming a smart sustainable city in the form of phases (Ibrahim *et al.,* 2016; Withers *et al.,* 2012). Frameworks, in turn, aim to provide tools and detailed guidance on how to achieve the objectives related to the stages of a roadmap. The roadmap developed serves as a foundation for the future development of a framework for smart sustainable city transformation (Ibrahim *et al.,* 2018).

x. Frameworks (21%): Frameworks are needed to provide the required guidance to planners and stakeholders in order to turn the phases of a roadmap into actionable steps and solutions (Di Biase, 2015; Borowik *et al.,* 2015). According to (Ibrahim *et al.,* 2018) a framework can also serve an additional function as a generic list of the areas of importance related to the priority dimensions that need to be observed when initiating a transformation, process or project. The smart sustainable city (SSC) frameworks that fall within the primary literature selection of this review relate to big data ICT and analytics (Bibri and Krogstie, 2018; Bibri, 2018), SSC evaluation analytics (Wey and Ching, 2018; Ahvenniemi *et al.,* 2017), analytics for SSC energy (Kramers *et al.,* 2014), urban transitioning for climate change (Göpfert *et al.,* 2019) and

complex adaptive systems (Nel *et al.,* 2018). Ibrahim *et al.* (2016) conclude their research by encouraging the development of a potential smart sustainable city transformation framework that builds upon the developed roadmap. Ibrahim *et al.* (2016) perceive such a framework as a layered structure to lead city planners and stakeholders through the process of transformation and developing innovative solutions for city sustainability and quality of life.

DISCUSSION

There is a scarcity of literature and absence of frameworks to guide city-level planning, implementation and management of smart sustainable city transitions from a holistic perspective. The research by Ibrahim *et al*. (2018) developed a transformation readiness roadmap indicating the main phases of the overall transformation process towards a smart sustainable city. The roadmap does not provide detailed steps to accomplish the goals outlined in the phases due to lacking availability of relevant and detailed literature on smart sustainable city development at the time. For this reason Ibrahim *et al*. (2018) encouraged future research that extends on their work through the development of a transition framework for smart sustainable cities.

A systems perspective

Cities comprise of various complex systems that are interconnected to form larger systems-of-systems (Tiwari, 2016; Larasati *et al.,* 2018). The components within these systems are diverse (Tiwari, 2016) and their interactions with one another lead to emergent behaviour in the system and cascading effects across other systems. Many urban systems possess the ability to adapt and self-organise (Nel *et al.,* 2018), and function at multiple nested levels (Kivimaa *et al*., 2019). Complex adaptive systems are known by these characteristics and cities are a typical example of this (Roggema, 2012).

Although Ibrahim et al. (2018) selected the theory of change (ToC) as theoretical foundation during the development of the smart sustainable cities transformation readiness roadmap, Ibrahim *et al.* (2018) believe this provides other researchers with the opportunity to explore other theories for transformation towards smart sustainable cities. The proposed research will investigate urban transitioning approaches from a systems perspective, which has emerged as the dominant school of thought relevant from the sustainable city, smart city and urban transitioning domains (Olazabal, 2017; Abbas *et al.,* 2019; Nel *et al.,* 2018). It is also inter-weaved in the recent research that has emerged regarding smart sustainable cities due to its appropriateness.

Infrastructure as intervention point

Sustainable urban development requires interventions in the built environment and infrastructural systems. The self-organising behaviour within cities as complex adaptive systems can be leveraged to adapt within well-structured infrastructure networks that function as a new skeleton for the co-evolution of social and environmental systems (Cole, 2012; Nel *et al.,* 2018).

Infrastructure not only for aesthetic or efficiency, but most important to guide and predetermine how a city is used and how it functions (Neal, 2012). Infrastructure networks, which also includes information and communication technologies (ICT), serves as a crucial support system to society (Höjer and Wangel, 2015).

Proper planning and strategic management or the absence thereof, determines whether infrastructure contributes as an enabler of societal and economic growth and environmental management, or, a contributing agent of growing inequality and accelerated resource exploitation and depletion (Höjer and Wangel, 2015). Failure of infrastructure systems can have high impact reaching as far as a global level, potentially affecting global economy, climate and national securities. Infrastructure networks of high concern include energy, mobility, food, water, finance and ICT (USA PATRIOT Act of October 26, 2001). These networks are interdependent, thus a collapse of one system will have a ripple effect on the interconnected system-of-systems it is embedded in. The additional pressures that result on the rest of the interconnected infrastructures cause cascading effects that amplify the disruptive impacts (Ryan, 2017).

Infrastructure is selected as the primary focus of the study as a purposeful intervention pathway for a smart sustainable city transition. Hereby the proposed framework will focus on various aspects needed for successful planning and execution of the multi-project transitioning of the city.

CONCLUSION

The rise of the digital revolution is observed in urban form as smart city technologies and initiatives become more common-place. Smart cities are known for various advantages such as efficiency, autonomy and real-time data to name a few. Despite the concerns of a chasm between the goals and design of smart cities versus sustainable cities, smart technology can be a powerful enabler and leverage to reach sustainability goals and solve urban challenges. Smart sustainable cities have emerged as a new urban concept to address complex challenges within cities.

This paper presents a systematic review regarding the transitioning of current cities to smart sustainable cities. The literature review entailed the identification and investigation of the nature of relevant literature available to address the research problem, which lead to the following main observations:

i. The knowledge available to understand and guide transitions towards smart sustainable cities is very fragmented, and there is a need for a holistic, comprehensive guide organised for this purpose.
ii. There is an absence of such a holistic framework to guide the planning, implementation and management of smart sustainable city transitions.
iii. Cities are increasing in complexity, population, diversity, autonomy and emergent change, properties that are characteristic of complex adaptive systems. It has become increasingly clear that complex adaptive systems theory provides a meaningful lens through which cities and transitions can be investigated and understood.
iv. Infrastructure is identified as a meaningful point of intervention to transition existing cities towards smart sustainable cities.

Future work planned entails the development of a framework to guide the planning, implementation and management of smart sustainable city infrastructure transitions from literature. This framework will also undergo verification and validation to ensure its effectiveness and feasibility.

REFERENCES

Abbas, H., Shaheen, S. and Amin, M. (2019). Engineering Large Complex Critical Infrastructures of Future Smart Cities as Self-adaptive Systems. In: Security in Smart Cities: Models, Applications, and Challenges, pp. 143–170.

Acuto, M., Parnell, S., Allen, A. and Bai, X. (2018). Science and the Future of Cities: Report on the global state of the urban science-policy interface. pp. 1–59.

Agrawal, G. (2017). Securing the rights of pedestrians is the key to smart, sustainable cities: A law and policy approach. pp. 354–366. American Society of Civil Engineers (ASCE).

Ahvenniemi, H., Huovila, A., Pinto-Seppä, I. and Airaksinen, M. (2017). What are the differences between sustainable and smart cities? Cities, vol. 60, pp. 234–245.

Aina, Y. (2017). Achieving smart sustainable cities with GeoICT support: The Saudi evolving smart cities. Cities, vol. 71, pp. 49–58.

Akande, A., Cabral, P., Gomes, P. and Casteleyn, S. (2019). The Lisbon ranking for smart sustainable cities in Europe. Sustainable Cities and Society, vol. 44, pp. 475–487.

Bhattacharya, T., Bhattacharya, A., Mclellan, B. and Tezuka, T. (2018). Sustainable smart city development framework for developing countries. Urban Research and Practice, vol. 0, no. 0, pp. 1–33.

Bibri, S. (2018). A foundational framework for smart sustainable city development: Theoretical, disciplinary, and discursive dimensions and their synergies. Sustain- able Cities and Society, vol. 38, pp. 758–794.

Bibri, S. and Krogstie, J. (2017). Smart sustainable cities of the future: An extensive interdisciplinary literature review. Sustainable Cities and Society, vol. 31, pp. 183–212.

Bibri, S. and Krogstie, J. (2018). The big data deluge for transforming the knowledge of smart sustainable cities: A data mining framework for urban analytics. pp. 1–10. Association for Computing Machinery.

Bibri, S. and Krogstie, J. (2019a). Generating a vision for smart sustainable cities of the future: a scholarly backcasting approach. European Journal of Futures Research, vol. 7, no. 1.

Bibri, S. and Krogstie, J. (2019b). A scholarly backcasting approach to a novel model for smart sustainable cities of the future: strategic problem orientation. City, Territory and Architecture, vol. 6, no. 1.

Bibri, S. and Krogstie, J. (2019c). Towards a novel model for smart sustainable city planning and development: A scholarly backcasting approach. Journal of Futures Studies, vol. 24, no. 1, pp. 45–62.

Bifulco, F., Tregua, M., Amitrano, C. and D'Auria (2016). ICT and sustainability in smart cities management. International Journal of Public Sector Management, vol. 29, no. 2, pp. 132–147.

Borowik, G., Chaczko, Z., Jacak, W. and Łuba, T. (2015). Computational Intelli- gence and Efficiency in Engineering Systems, vol. 595 of Studies in Computational Intelligence. Springer International Publishing.

Brundtland, G. (1987). Report of the World Commission on Environment and Development: Our Common Future. United Nations, Oxford University Press, Oxford.

Cole, R. (2012 01). Transitioning from Green to Regenerative Design. Building Research & Information, vol. 40, pp. 39–53.

Di Biase, S. (2015). Applied Innovation: A Handbook. Premier Insights LLC.

Dinh Dung, N. and Rohacs, J. (2019). Smart city total transport-managing system: (a vision including the cooperating, contract-based and priority transport management). Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering, LNICST, vol. 257, pp. 74–85.

Elgazzar, R. and El-Gazzar, R. (2017). Smart Cities, Sustainable Cities, or Both? A Critical Review and Synthesis of Success and Failure Factors. In: In Proceedings of the 6th International Conference on Smart Cities and Green ICT Systems, Porto, Portugal, pp. 22–24.

Geldenhuys, H.J. Brent, A.C. and de Kock, I.H. (2018). Literature review for infrastructure transition management towards Smart Sustainable Cities. IEEE International Systems Engineering Symposium (ISSE), Rome, 2018, pp. 1-7.

Göpfert, C., Wamsler, C. and Lang, W. (2019 Jan). A framework for the joint institutionalization of climate change mitigation and adaptation in city administrations. Mitigation and Adaptation Strategies for Global Change, vol. 24, no. 1, pp. 1–21.

Höjer, M. and Wangel, J. (2015). Smart Sustainable Cities: Definition and Challenges, pp. 333–349. Springer International Publishing.

Ibrahim, M., El-Zaart, A. and Adams, C. (2016). Smart Sustainable Cities: A New Perspective on Transformation Roadmap and Framework Concepts. In: The Fifth International Conference on Smart Cities, Systems, Devices and Technologies (includes URBAN COMPUTING 2016), IARIA, pp. 8–14.

Ibrahim, M., El-Zaart, A. and Adams, C. (2017). Stakeholders Engagement in Smart Sustainable Cities: A Proposed Model. In: 2017 International Conference on Computer and Applications (ICCA), pp. 342–347.

Ibrahim, M., El-Zaart, A. and Adams, C. (2018). Smart sustainable cities roadmap: Readiness for transformation towards urban sustainability. Sustainable Cities and Society, vol. 37, pp. 530–540.

Kivimaa, P., Boon, W., Hyysalo, S. and Klerkx, L. (2019). Towards a typology of intermediaries in sustainability transitions: A systematic review and a research agenda. Research Policy, vol. 48, no. 4, pp. 1062–1075. New Frontiers in Science, Technology and Innovation Research from SPRU's 50th Anniversary Conference.

Kramers, A., Höjer, M., Lövehagen, N. and Wangel (2014). Smart sustainable cities - Exploring ICT solutions for reduced energy use in cities. Environmental Modelling & Software, vol. 56, pp. 52–62.

Larasati, N., Handayaningsih, S. and Sumarsono, S. (2018 Dec). Smart Sustainable City Application: Dimensions and Developments: Smart services for region of the foremost cultural centers of a developing country. In: 2018 IEEE 3rd International Conference on Communication and Information Systems (ICCIS), pp. 122–126.

Neal, Z. (2012). The Connected City: How Networks are Shaping the Modern Metropolis. The Metropolis and Modern Life. Taylor & Francis.

Nel, D., du Plessis, C. and Landman, K. (2018). Planning for dynamic cities: introducing a framework to understand urban change from a complex adaptive systems approach. International Planning Studies, vol. 23, no. 3, pp. 250–263.

Olazabal, M. (2017). Resilience, Sustainability and Transformability of Cities as Complex Adaptive Systems, pp. 73–97. Springer Fachmedien Wiesbaden, Wies- baden.

Perlman, J. and Sheehan, M. (2007). Fighting poverty and environmental injustice in cities. State of the World, p. 172.

Roggema, R. (2012). Swarm planning: The development of a planning methodology to deal with climate adaptation. Springer Theses. Springer Science & Business Media.

Ryan, D. (2017). Engineering sustainable critical infrastructures. International Journal of Critical Infrastructure Protection, vol. 17, pp. 28–29.

Teremranova, J. and Mutule, A. (2019 March). Sustainable City Development as a Result of Close Cooperation with Citizens: Europe and LAC Experiences. In: 2019 11th International Symposium on Advanced Topics in Electrical Engineering (ATEE), pp. 1–6.

Timashev, S. (2017). Resilient Urban Infrastructures - Basics of Smart Sustainable Cities. IOP Conference Series: Materials Science and Engineering, pp. 1–6.

Tiwari, A. (2016). Urban Infrastructure Research: A Review of Ethiopian Cities. Springer Briefs in Geography. Springer International Publishing.

UN-DESA (2015). United Nations, Department of Economic and Social Affairs: The millennium development goals report 2015.

Wey, W.-M. and Ching, C.-H. (2018). The Application of Innovation and Catapult Research Techniques to Future Smart Cities Assessment Framework. In: 2018 International Conference on System Science and Engineering (ICSSE), pp. 1–6. New Taipei, Taiwan.

Withers, M., Williams, M. and Reddington, M. (2012). Transforming HR: Creating value through people. 2nd edn. Elsevier Ltd.