# ACHIEVING DECARBONISATION THROUGH SUSTAINABLE SMART CITY TECHNOLOGIES

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The concept of Sustainable Smart City (SSC) has been promoted as an ideal model that promises to enhance the efficiency of city governance and improve sustainability by taking advantage of technological innovations. Despite the rise of SSC initiatives and research worldwide, it is difficult to establish whether SSC really delivers Decarbonisation solutions or is a techno-centric fantasy to control the effects of the environment with modern technology. The main problem of carbon emissions relates to excessive consumption behaviour, which hinges on the social lifestyle and wellbeing needs of urban citizens. In this research, we have considered Decarbonisation as a movement ingrained in the social fabric of society to address these behavioural issues. This study aims to assess the extent of SSC models' approach to Decarbonisation which stems from social behaviour problems that cause high carbon emissions. Based on selected key words, a systematic literature review was carried out to understand main themes within four publication databases. Upon screening, 115 papers were used for thematic analysis to evaluate the extent of social and behavioural considerations to reduce carbon emissions. The results revealed three overarching themes that mainly sought to define SSC, describe the pathway to achieve SSC, and understand the impact of SSC. Majority of the studies focussed on conceptual definition and descriptive indicators to mark the way forward towards SSC. Only a small proportion (11%) of papers discussed about social engagement and participation to affect the necessary changes for SSC and had limited relevance to carbon reduction. The findings show a disconnection between the political ambitions of SSC models and the social demands of urban citizens that drive carbon emissions. This paper contributes new insight on the lack of focus on social behaviour in SSC models, specifically in achieving Decarbonisation solutions at a local level.

Keywords: smart city, sustainability, sociology, environmental impact, urbanisation

## INTRODUCTION

Over the last decade, the need for better-quality cities has inspired growing interest in research on sustainable smart cities (SSC) (Trindade *et al.,* 2017). To achieve sustainability goals in urban developments, the use of smart technology was introduced as a means for enabling the intelligent use of digital information in order to provide better governance, energy management, education and mobility. The development of techno-centric solutions to support low carbon transitions foregrounded the role of technology in achieving a sustainable future (Stripple, 2019). Although SSC emerge as a popular contemporary concept today, its origin is related to the sustainable development agenda in 1970. In theory, smart cities are seen as inclusive of addressing sustainability goals but there are limited empirical evidence to

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support this (Yigitcanlar, 2018). Smart technologies are believed to help cities forward the sustainability agenda through the emerging roles of information and communication technology (ICT) in policy design and urban planning (Yigitcanlar and Kamruzzaman, 2018). This has driven the rise of over 5550 smart cities worldwide (Joss *et al.,* 2019). However, the term "smart city" lacks a universally accepted definition among researchers, practitioners, and the media (Alawdah, 2017). As a result, many smart cities simply adopt technological interventions such as Internet of Things (IoT) to improve the efficiency of their urban management operations (Yigitcanlar and Lee, 2014). The view focuses on a governmental perspective of smart city planning. Equally important is the role of citizens in smart cities to ensure the success of smart city aspirations at a local level (Kummitha; 2017). The use of big data in smart cities is meant to increase the efficiency of decision-making for urban citizens (Beneicke *et al.,* 2020). However, it is not known whether this has an impact on reducing carbon emissions. In this research, Decarbonisation is considered from a sociological perspective, focusing on societal activities in the smart city community. The purpose of this paper is to examine the extent of SSC models' approach to Decarbonisation which stems from social behaviour problems that cause high carbon emissions.

# RATIONALISATION

## Social Perspective of the Sustainable Smart City Vision

SSC is increasingly advocated around the world as the primary means to address the sustainability agenda and has prompted the development of policies and procedures relating to city planning (De Jong *et al.,* 2015). Its vision focuses on an urban environment with sophisticated infrastructure supported by optimised digital data that provides efficient interconnectivity and wide information access. However, these policies are mainly driven by economic gains and engineering solutions. De Jong *et al.,* (2015) stated that not much is known about SSC from a sociological standpoint such as its effect on social equity or environmental improvement. There is a need for further research to understand the implications of urban development policy and practice from this perspective. The goal of urban sustainability was really to create a utopia where people could live in idealistic conditions (Lyons, 2018). This is a grandiose dream which requires monumental effort in understanding the context of people's lifestyles, constraints, needs, desires and behaviours in order to create the perfect environment. The 'smart' component only exists as a vehicle that facilitates this endeavour through the interaction between humans and technology (Lyons, 2018). Ultimately, SSC should improve people's quality of life (Callaway, 2016). An ethnographic perspective of cities as a symbiotic system of multiple actors, priorities, and solutions is therefore fundamental to establish creative ways of transitioning towards the SSC vision (Shin, 2014). This requires a holistic approach to city design from governance strategies to social development. However, literature on SSC have been focussed on technological solutions and political strategies, whereas not enough attention has been given to social inclusion in urban innovation (Paskaleva *et al.,* 2017). New studies are needed in the area of SSC to examine the impacts of SSC models on bettering society, specifically in cultivating Decarbonisation practices.

## Decarbonisation as a Measure of Sustainability

Decarbonisation was identified as a critical step in Article 2.1 of the Paris Agreement as part of the sustainability pathway (UNFCCC, 2020), indicating the need for major technological and institutional changes in the energy supply and demand. This can be

difficult due to the inevitable challenges on a practical level. Although many political leaders have introduced initiatives to support investment in low carbon technologies for energy supply, this says nothing about the social behavioural changes needed from the demand side (UNA-UK, 2020). One of the key challenges is the ability for individual energy users to reduce energy demand and increase energy efficiency through energy conservation measures and behavioural practices (Foxon, 2013). However, behavioural practices related to energy choices are particularly difficult to change as they are rooted in cultural meanings (Hargreaves *et al.,* 2010). Thus, changes need to be ingrained in the individual consumption behaviour and lifestyle to influence wider changes in the social environment.

### Decarbonisation in Sustainable Smart Cities

Without a standard definition, the ambiguity caused by the diverse range of descriptions and models of SSC has left it open to various interpretations (Alawdah, 2017). It difficult to establish whether SSC really delivers Decarbonisation solutions or is a techno-centric fantasy to control the effects of the environment using modern technology. The main problem of carbon emissions relates to excessive consumption behaviour, which hinges on the social lifestyle and wellbeing needs of urban citizens (Heinonen and Junnila, 2011). Household consumptions for example, affect 20% of carbon emissions in Europe (Eurostat, 2017). This shows that radical changes in social behaviour from personal transport, thermal energy use, electricity consumption, and other consumption behaviours can significantly reduce carbon emissions (Kalbar *et al.,* 2016). Thus, while SSC emphasise on technological interventions as a means to achieve sustainability, it cannot effectively do so without also introducing interventions that transform the social behaviour of urban citizens. The challenge with this is that the very social and economic system in which humans live is based on consumption behaviours that detrimentally affect social and environmental wellbeing (Lawrence and Friel, 2019). Committing to Decarbonisation therefore means reinventing the social and economic system governing social consumption behaviour. In this research, we have considered Decarbonisation as a movement ingrained in the social fabric of society to address these behavioural issues. This approach differs from previous studies as it focuses on the gentrification of urban society's consumption behaviour and lifestyle, rather than the philosophical view of a contemporary metropolis. While many scholars have emphasised the key role of social behaviour in affecting Decarbonisation, it is not clear from the current literature whether SSC models evoke behavioural changes at a local level. The literature review shows a gap in understanding how SSC research has addressed Decarbonisation from a sociological view. This raises the question of how much SSC models consider Decarbonisation through social behavioural changes and how can they be achieved. The study aims to assess the extent of SSC models' approach to Decarbonisation which stems from social behaviour problems that cause high carbon emissions through a systematic literature review method.

## METHODOLOGY

The study employed a systematic review method to examine the overarching themes in SSC literature. Early reviews of articles focusing on 'sustainable and smart cities' over the past decade indicated a body of knowledge that is increasingly fragmented as well as being interdependent. In order to fully understand the prior research in this field, a systematic literature review was undertaken. The method of scientific investigation followed the work of Tranfield *et al.,* (2003) who developed a systematic

review methodology for evidence-informed management knowledge. The systematic review process included three different stages; planning the review, conducting a review and reporting and dissemination (Tranfield *et al.,* 2003). Planning the review started with establishing the need for undertaking a review by exploring the existing body of knowledge in the relevant field. The second stage begins with conducting a thorough search to identify relevant studies and document the search with assessment of their quality. Data extraction forms were proposed for this purpose, followed by data synthesis. Finally, a succinct report was produced for reporting and dissemination purposes. The modified systematic review process, which comprises a number of distinct phases, is illustrated in Figure 1.

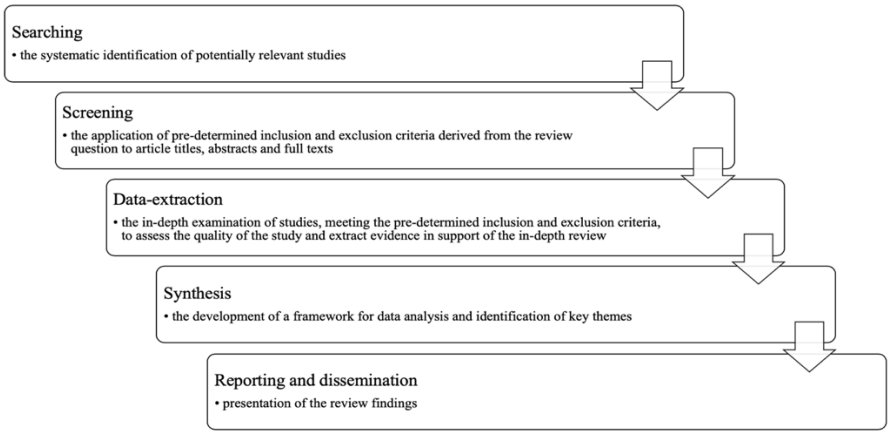


*Figure 1: Systematic literature review process*

The first stage of the systematic review process involves the identification of research papers and research reports that were broadly concerned with smart and sustainable cities. After an initial survey of related articles and references, appropriate electronic databases and websites were selected for this purpose. Potentially relevant papers were identified from these sources, using a predetermined search strategy. The databases used include Business Source Premier EBSCO, Scopus, Science Direct (Elsevier) and Web of Science. These were selected for its large catalogue of scholarly journals and peer-reviewed publications, as well as the ability to conduct advanced search using Boolean logic. In order to assess the relevance and size of the literature, the scope of the literature review process was delimited by factors of disciplinary perspective, keywords and quality of the research sources. The search included full-text articles from the last 20 years that focused on 'smart and sustainable city' discourse. A combination of three keywords were used to form a search string. All searches therefore included the key terms “smart”, “sustainable”, and “city” in publication titles. The initial search acquired 1078 articles. Screening of relevant articles was executed in order to ascertain whether the documents were likely to meet pre-determined inclusion and exclusion criteria.

The inclusion criteria included:

- Published papers/articles since 2000
- Papers/articles in English language
- Papers/articles that specifically address smart AND sustainable cities
- Papers/articles with empirical and non-empirical evidence
- Scholarly and non-scholarly papers/articles

In addition, the following exclusion criteria was applied:

- Papers/articles published in magazines and newspapers

- Papers/articles that only provide a review of a conference

*Table 1: Search results, fully reviewed papers, and included papers*

| | Search results | |
|---|---|---|
| Initial search | | 1078 |
| Duplicate removal | (209) | |
| Abstract screening | (721) | 869 |
| Full text screening | (33) | 148 |
| Final in-depth review | | 115 |

Table 1 summarises the screening and review process of the search results to only 115 articles included for in-depth analysis. The papers were analysed using thematic analysis to identify themes across the dataset at the semantic level that reflected the explicit content of the data (Braun and Clarke, 2006). The analysis was driven by an inductive approach using open coding in which codes were developed and modified through the coding process based on the available content. These were then arranged into semantic themes. The research analysed the ways in which Decarbonisation in SSC research was explored and sought to identify any significant patterns. By understanding the existing literature, we identified three questions and developed these into themes: 1) what a sustainable smart city is, 2) how we can achieve sustainable smart city, and 3) what affects the process of sustainable smart cities. The papers were categorically clustered according to the scope and focus of the paper: whether they addressed the definition and taxonomy of SSC, methodologies and strategies of achieving SSC, or examined the practicalities of SSC operations. Each category responded to an overarching question. The papers were then examined to reveal existing gaps.

# RESULTS

Articles responding to the first question (37%) seek to define SSC either conceptually or practically using principles, indicators, frameworks, models, and theoretical discourse. The second question, which bears the largest group of articles (50%) focused on methodologies, strategies, policy-design, technological tools, and case study exemplars to elucidate ways of achieving SSC. The third question was addressed by only a few articles (11%), which drew attention to the interdependencies of social governance and realisation of SSC.

## What is Sustainable Smart City?

More than a third of papers (37%) had attempted to define and clarify what SSC is. Papers answering this question can be categorised into two themes i.e. discussion of the concept and describing what SSC should look like. Most of the papers approached this by explaining what the SSC represents, while others have extended this into a framework to demarcate the various dimensions of SSC. Scholars debate the SSC hypotheses by making logical comparisons and evaluations of previous concepts, terminologies, and its associated meanings. According to Kobayashi, *et al.,* (2017), the concepts of sustainable city and smart city had converged over time to mean the same. The concept and specific characteristics of SSC however, remained obscure (Kobayashi *et al.,* 2017). Some scholars adopted a systems-thinking approach in which SSC is viewed as a combination of various dimensions and actors interacting in a harmonious effort (Hecht *et al.,* 2019; Ibrahim, El-Zaart, and Adams, 2018; Ramaswami *et al.,* 2016). Others focused on a specific element such as technology as

a tool enabling effective governance (Yadav, 2019; Bardell, 2018) or understanding the social context in response to technology (Aurigi and Odendaal, 2020; Lyons, 2018). The general notion of a SSC reflected a sophisticated and modern environment that led to the improvement in quality of life (Callaway, 2016). To measure this, key performance indicators (KPIs) were proposed, either focussing on specific aspects as part of SSC (Li *et al.,* 2020; Zhang and Pu, 2019) or a group of variables (Akande *et al.,* 2019; Chudiniva and Afonina 2018). The lack of homogeneity between indicators can be confusing as these are adapted based on the needs and goals of the city (Nevado *et al.,* 2020; Huovila *et al.,* 2019). While many studies have tried to define SSC in either prescriptive or malleable terms, it is not yet clear what extent of social equity and environmental progress can be achieved (De Jong *et al.,* 2015).

**How Can We Achieve Sustainable Smart City?**

This question aims to explore how the SSC can be realised. The majority of studies (50%) looked for pathways to support the SSC vision either through designing political strategies or technical methodologies. Many of these identified the need for policies and regulations to enable smart processes in SSC (Behrendt, 2019) and highlighted the importance of social participation and engagement (Paskaleva *et al.,* 2017). Others focussed on a more technical approach, identifying smart applications (Sodhro, *et al.,* 2019; Angelidou, *et al.,* 2018) and methodologies (Bibri, 2018) in SSC planning. In some countries, smart city approach was simply focussed on the development of infrastructure such as transportation, water management, waste management, streetlights, and disaster management (Basumatary and Anand, 2018). Despite there being various approaches proposed for SSC development, the process of smart city development is complex and there is no unified approach that could guarantee the efficiency of urban management or Decarbonisation. The implementation of SSC could only succeed with significant improvements in the power efficiency of certain buildings, infrastructure, and the overall city administration (Krupkin and Gorodnova, 2018). Brorström, *et al.,* (2018) argued that values of sustainability and smartness can be integrated into cities by introducing a central vision and strategy that pushes organisational practices and individual actions to gradually change at a local level. However, this is only possible if stakeholders are equipped and willing to apply the necessary changes to affect the SSC vision (Duvier *et al.,* 2018). This emphasises the influence of local context on the implementation of smart cities as even though ICT infrastructure is necessary to SSC, it is not sufficient without the relevant social adaptations (Aurigi and Odendaal, 2020).

**What Affects the Process of SSC?**

Articles in this category aim to gain an understanding of the impact of SSC by examining the relationships between the ideal city factors and society, as well as review the success of tools and models used to deliver SSC. Of the 115 papers analysed, only 11% of studies explored this. Many studies examined specific cities as case studies to develop an understanding of the city's approach to SSC and the corresponding impacts on social wellbeing and environmental sustainability. Some cities emphasised on the use of ubiquitous technology to improve infrastructures and services (Yadav *et al.,* 2019). However, cities that included people engagement as part of its solution were deemed more effective and successful as SSC (Wendling *et al.,* 2018; Kankaala *et al.,* 2018; Zelinka *et al.,* 2016). The notion inspires the need for a methodology that could objectively measure the quality of urban life and the social behaviour norms in SSC (Garau and Pavan, 2018). Although many researchers

have advocated the inclusion of social participation in the SSC model, there was no coherent link between social activities and the evolution process from traditional models (Bednarska-Olejniczak *et al.,* 2019). This corresponds to the need for a unified link between culture, governance and procurement to enable the transition towards SSC (Fassam, *et al.,* 2016). Despite the recognition of the importance of social participation, there was limited discourse on its correlation to carbon reduction. There is scant evidence on a smart city's ability to enhance social well-being, build just and equitable communities, reduce resource consumption and waste generation, improve environmental quality or lower carbon emissions (Evans *et al.,* 2019). The success of SSC models depends on societal structures through social practices and interactions (Bibri and Krogstie, 2017). As societies become more advanced, our patterns of consumption have critically intensified to accommodate increasing demands for housing, urban travel, and domestic goods (Newton and Meyer, 2012). So far, current SSC models have acknowledged the importance of social inclusion, but the practical implementations have not considered what this means for social behaviour changes and how this can be realistically achieved. This shows a disconnection between the political ambitions of SSC models and the social demands of urban citizens that drive carbon emissions. While lower carbon emission is envisioned as a benefit of SSC, the evidence is erratic as Decarbonisation was not addressed as the main crusade for social engagement. A paradigm shift in the approach to city development is needed to bridge the gap between SSC ideals and socially anchored practices.

## CONCLUSIONS

The concept of SSC has seen growing attention as a fundamental pathway to a low carbon future. The notion is underpinned by the assumption that SSC will drive Decarbonisation by increasing energy efficiency of urban operations and infrastructure systems. However, this does not say anything about reducing the demand for energy use from consumption behaviour changes in society, which plays a significant role in determining decarbonisation achievements. The study identified three overarching themes in SSC research based on the systematic review of 115 studies that considered a social dimension of SSC. The analysis revealed that although many scholars highlighted the importance of social participation in SSC, it is unclear whether social transformations actually occur leading to successful Decarbonisation achievements. There is surprisingly little evidence to suggest that SSC models drive Decarbonisation initiatives on a practical level. This is worrying and could be connected to the limited research considering Decarbonisation as a social effort embedded as part of socially anchored practices. Hence there is a need to explore the social perspective of SSC development to elucidate the Decarbonisation implications of urban maturity.

## REFERENCES

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

Alawdah, A (2017) *An Exploratory Study of Smart City Initiatives: Theory, Practice and Linkage to Sustainability*, Southfield, MI: Lawrence Technological University.

Angelidou, M, Psaltoglou, A, Komninos, N, Kakderi, C, Tsarchopoulos, P and Panori, A (2018) Enhancing sustainable urban development through smart city applications, *Journal of Science and Technology Policy Management*, **9**(2), 146-169.

Aurigi, A and Odendaal, N (2020) From smart in the box to smart in the city: Rethinking the socially sustainable smart city in context, *Journal of Urban Technology*, 1-16.

Bardell, A (2018) Living in a sustainable smart city, *ITNOW*, **60**(1), 52-55.

Basumatary, M G and Anand, S (2018) Sustainable urban infrastructural development for smart city in Guwahati, *India Human Geography Journal*, **25**, 54-65

Bednarska-Olejniczak, D, Olejniczak, J and Svobodová, L (2019) Towards a smart and sustainable city with the involvement of public participation - The case of Wroclaw, *Sustainability*, **11**(2), 332.

Behrendt, F (2019) Cycling the smart and sustainable city: Analysing EC policy documents on internet of things, mobility and transport and smart cities, Sustainability, **11**(3), 763.

Beneicke, J, Juan, A A, Xhafa, F, Lopez-Lopez, D and Freixes, A (2019) Empowering citizens' cognition and decision making in smart sustainable cities, *IEEE Consumer Electronics Magazine*, **9**(1), 102-108.

Bibri, S E and Krogstie, J (2017) On the social shaping dimensions of smart sustainable cities: A study in science, technology and society, *Sustainable Cities and Society*, 29, 219-246.

Bibri, S E (2018) Backcasting in futures studies: A synthesized scholarly and planning approach to strategic smart sustainable city development, *European Journal of Futures Research*, **6**(1), 1-27.

Braun, V and Clarke, V (2006) Using thematic analysis in psychology, *Qualitative Research in Psychology*, **3**, 77-101.

Brorström, S, Argento, D, Grossi, G, Thomasson, A and Almqvist, R (2018) Translating sustainable and smart city strategies into performance measurement systems, *Public Money and Management*, **38**(3), 193-202.

Callaway, L (2016) Smart cities: The future of sustainable living, *Renewable Energy Focus* **17**(3), 106-108.

Chudiniva, O and Afonina, M (2018) Formation of urban planning indicators for smart city concept (on the example of SKOLKOVO, Moscow), *In*: *MATEC Web of Conferences, **170**,* 02021.

De Jong, M, Joss, S, Schraven, D, Zhan, C and Weijnen, M (2015) Sustainable-smart-resilient-low carbon-eco-knowledge cities: Making sense of a multitude of concepts promoting sustainable urbanization, *Journal of Cleaner Production*, **109**, 25-38.

Duvier, C, Anand, P B and Oltean-Dumbrava, C (2018) Data quality and governance in a UK social housing initiative: Implications for smart sustainable cities, *Sustainable Cities and Society*, **39**, 358-365.

Eurostat (2017) *Greenhouse Gas Emissions Statistics - Air Emissions Accounts*, Available from https://ec.europa.eu/eurostat/statistics-explained/index.php/Greenhouse_gas_emission_statistics_-_air_emissions_accounts [accessed 16 April 2020].

Evans, J, Karvonen, A, Luque-Ayala, A, Martin, C, McCormick, K, Raven, R and Palgan, Y V (2019) Smart and sustainable cities? Pipedreams, practicalities and possibilities, *Local Environment*, **24**(7), 557-564.

Fassam, L, Copsey, S and Gough, A (2016) Network Northamptonshire: Total transport smart city procurement theoretical framework for sustainable economic and social change, *International Journal of Advanced Logistics*, **5**(3-4), 117-124.

Foxon, T J (2013) Transition pathways for a UK low carbon electricity future, *Energy Policy*, **52**, 10-24.

Garau, C and Pavan, V (2018) Evaluating urban quality: indicators and assessment tools for smart sustainable cities, *Sustainability*, **10**(3), 575.

Hecht, B, Valaskova, K, Kral, P and Rowland, Z (2019) The digital governance of smart city networks: information technology-driven economy, citizen-centred big data and sustainable urban development geopolitics, *History and International Relations*, **11**(1), 128-133.

Heinonen, J and Junnila, S (2011) A carbon consumption comparison of rural and urban lifestyles, *Sustainability,* **3**(8), 1234-1249.

Huovila, A, Bosch, P and Airaksinen, M (2019) Comparative analysis of standardized indicators for Smart sustainable cities: What indicators and standards to use and when? *Cities*, **89**, 141-153.

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

Joss, S, Sengers, F, Schraven, D, Caprotti, F and Dayot, Y (2019) The smart city as global discourse: Storylines and critical junctures across 27 cities, *Journal of Urban Technology*, **26**(1), 3-34.

Junior, C M, Ribeiro, D M, da Silva Pereira, R and Bazanini, R (2018) Do Brazilian cities want to become smart or sustainable? *Journal of Cleaner Production*, **199**, 214-221.

Kalbar, P P, Birkved, M, Kabins, S and Nygaard, S E (2016) Personal metabolism (PM) coupled with life cycle assessment (LCA) model: Danish case study, *Environment International*, **91**, 168-179.

Kankaala, K, Vehiläinen, M, Matilainen, P and Välimäki, P (2018) Smart city actions to support sustainable city development, *TECHNE - Journal of Technology for Architecture and Environment*, **1**, 108-114.

Kobayashi, A R K, Kniess, C T, Serra, F A R, Ferraz, R R N and Ruiz, M S (2017) Smart sustainable cities: Bibliometric study and patent information, *International Journal of Innovation*, **5**(1), 77.

Krupkin, A and Gorodnova, N (2018, June) Development of the smart city concept in sustainable economy, *In*: *IOP Conference Series: Materials Science and Engineering*, **365**(2), 022056.

Kummitha, R (2017) How do we understand smart cities: An evolutionary perspective, *Cities*, **67**, 43-52.

Lawrence, M and Friel, S (2019) *Healthy and Sustainable Food Systems*, Oxford: Routledge.

Li, M, Xu, K and Huang, S (2020) Evaluation of green and sustainable building project based on extension matter-element theory in smart city application, *Computational Intelligence*, 1-19.

Lyons, G (2018) Getting smart about urban mobility-aligning the paradigms of smart and sustainable, *Transportation Research Part a: Policy and Practice*, **115**, 4-14.

Nevado Gil, M T, Carvalho, L and Paiva, I (2020) Determining factors in becoming a sustainable smart city: An empirical study in Europe, *Economics and Sociology*, **13**(1), 24-39.

Newton, P and Meyer, D, 2012 The determinants of urban resource consumption, *Environment and Behaviour*, **44**(1), 107-135.

Paskaleva, K, Evans, J, Martin, C, Linjordet, T, Yang, D and Karvonen, A (2017) Data governance in the sustainable smart city, *Informatics*, **4**(4), 41.

Ramaswami, A, Russell, A G, Culligan, P J, Sharma, K R and Kumar, E (2016) Meta-principles for developing smart, sustainable and healthy cities, *Science*, **352**(6288), 940-943.

Shin, D (2014) A socio-technical framework for Internet-of-Things design: A human-centred design for the Internet of Things, *Telematics and Informatics*, **31**(4), 519-531.

Sodhro, A H, Pirbhulal, S, Luo, Z and de Albuquerque, V H C (2019) Towards an optimal resource management for IoT based Green and sustainable smart cities, *Journal of Cleaner Productio*n, **220**, 1167-1179.

Stripple, J B (2019) Towards a material politics of socio-technical transitions: Navigating decarbonisation pathways in Malmö, *Political Geography*, **72**, 52-63

Tranfield, D, Denyer, D and Smart, P (2003) Towards a methodology for developing evidence-informed management knowledge by means of systematic review, *British Journal of Managemen*t, **14**(3), 207-222.

UNA-UK (2020) *What Decarbonisation Really Means - Sustainable Goals*, United Nations Association-UK, Available from https://www.sustainablegoals.org.uk/decarbonisation-really-means/ [Accessed 9 June 2020].

UNFCCC (2020) *What is the Paris Agreement?* Available from https://unfccc.int/process-and-meetings/the-paris-agreement/what-is-the-paris-agreement [Accessed 9 June 2020].

Wendling, L A, Huovila, A, Castell-Rüdenhausen, M, Hukkalainen, M and Airaksinen, M (2018) Benchmarking nature-based solution and Smart City assessment schemes against the Sustainable Development Goal indicator framework, *Frontiers in Environmental Science*, **6**, 69.

Yadav, G, Mangla, S K, Luthra, S and Rai, D P (2019) Developing a sustainable smart city framework for developing economies: An Indian context, *Sustainable Cities and Society*, 47, 101462.

Yigitcanlar, T (2018) Smart city policies revisited: Considerations for a truly smart and sustainable urbanism practice, *World Technopolis Review*, **7**(2), 97-112.

Yigitcanlar, T and Kamruzzaman, M (2018) Does smart city policy lead to sustainability of cities? *Land Use Policy*, 73, 49-58.

Zelinka, T, Pribyl, O and Lom, M (2016) Smart as a key component of the sustainable city development, *Journal of Systemics, Cybernetics and Informatics*, **14**(5), 16-21.

Zhang, Y and Pu, H (2019) Environmental indicators of sustainable computing applications for smart city, *Concurrency and Computation: Practice and Experience*, **31**(9), e4751.