

Cities are the centers of enhanced engagements and productivity. They provide greater opportunities of employment, industrial and commercial activities. However, cities are also the key driver of environmental degradation consuming 70% of resources and contributing significant amount of greenhouse gas emissions (Bibri and Krogstie, 2017). The unplanned and rapid urbanization creates adverse effects, which can be mitigated by transforming the cities to accompany urban growth. The process of urban development is different for developed and developing countries. The development in context to developed countries may be taken as going through three phases: first from ‘Cities’ to ‘Sustainable Cities’, then from ‘Sustainable Cities’ to ‘Smart Cities’ and finally, towards ‘Smart Sustainable Cities’. From, the perspectives of Indian and similar developing countries, the process of future urban planning may take place in three phases: first from ‘Cities’ to ‘Smart Cities’, then from ‘Smart Cities’ to ‘Sustainable Smart Cities’ and finally, towards ‘Environmentally Sustainable Smart Cities (ESSC)’ which is yet to be explored. The framework for each development phase is discussed in detail as follows:

Cluster I: deals with Sustainable Cities, Smart Cities and related frameworks (Section 2.1 to Section 2.2)

Cluster II: deals with difference between the Sustainable and Smart cities and the development scenario of developed and developing countries (Section 2.3 to Section 2.5)

Cluster III: deals with Decision Support System and literature gap (Section 2.6 to Section 2.7)

Cluster I

2.1 Sustainable Cities

The concept of sustainability in developmental activities was introduced in 1987, which talked about three pillars of ‘sustainability’: social, environmental, and economic (WCED, 1987). In developed countries, the concepts of sustainability and sustainable development have been applied to urban planning and design since the 1990s. Visions for Green Cities (e.g., Campbell, 1996), Compact City (e.g., Jenks et al., 1996a, 1996b, Hofstad, 2012), Eco-cities (e.g., Joss, 2010, 2011; Joss et al., 2013) and Sustainable Cities (e.g., Girardet, 1999; Bulkeley and Betsill, 2005; Egger, 2006; Williams, 2009) were formed based on such considerations. Several frameworks incorporating different set of indicators have been developed for evaluation of sustainability and formulation of policies by decision makers. There is also growing interest in evaluating the implementation of policies by various organizations and how well they are satisfying their area specific objectives and global commitments.

Numerous frameworks are available to assess the sustainability, and depend on focus of the program. Organisation for Economic Co-operation and Development (OECD) of European Union in year 2001 came up with a set of 50 core indicators based on pressure-state-response (PSR) model to ensure the environmental concern into economic policies formulation and implementation for various sectors such as transport, energy and agriculture among the member countries of OECD (OECD, 2001). The World Bank Environment Department (WBED), in the year 2002, gave project based framework (Segnestam, 2002). The set of indicators in this framework intended to capture the effect of pressure and change in state to facilitate the decision-makers. The Pressure-State-Response (PSR) framework has been modified by WBED in three ways:

- i) As pressure indicator advocates only environmental issues, hence pressure was replaced by driving force resulting in DSR framework. Moreover, driving force explains both positive and negative impact on sustainability.
- ii) In the second scenario PSR framework was accordingly appended with “Impact” as fourth indicator category creating a pressure-state-impact-response (PSIR) model. Impact was added to capture the effects of pressures on state.
- iii) The final form was modelled as driving force-pressure-state-impact-response (DPSIR) framework, which provided one mechanism for analyzing environmental problems (Segnestam, 2002).

Cities (2012) presented ‘Indicators for sustainability report’. It considered case studies of different cities with different sizes and chose the indicators which were common and easy to implement. This resulted in a set of indicators which is flexible and capable to cover broad aspects of sustainability. The identified and finalized indicators were to support the cities in tracking their respective progress. The report focussed more on environmental sustainability rather than socio-economic issues. Economist Intelligence Unit (EIU) reported development of Green City Index (GCI) (EIU, 2012) to test the critical issues of environmental sustainability of more than 120 cities across seven continents on a set of 30 indicators divided in eight categories: i. CO₂ (3 indicators: CO₂ intensity, CO₂ emissions, CO₂ reduction strategy), ii. Energy (4 indicators: Energy consumption, Energy intensity, Renewable energy consumption, Clean and efficient energy policies), iii. Buildings (3 indicators: Energy consumption of residential buildings, Energy-efficient buildings standards, Energy-efficient buildings initiatives), iv. Transport (4 indicators: Use of non-car transport, Size of non-car transport network, Green transport promotion, Congestion reduction policies), v. Water (4 indicators: Water consumption, System leakages,

Wastewater system treatment, Water efficiency and ,treatment policies), vi. Waste & land use (4 indicators: Municipal waste production, Waste recycling, Waste reduction policies, Green land use policies, vii. Air quality (5 indicators: Nitrogen dioxide, Sulphur dioxide, Ozone, Particulate matter, clean air policies) and viii. Environmental governance (3 indicators: Green action plan, Green management, and Public participation in the green policy). About half of the indicators in each category are quantitative – usually based on data from official public sources - for example, CO₂ emissions per capita, water consumption per capita, recycling rates, and air pollutant concentrations. The remainder is qualitative assessments of the city's environmental policies – for example, the city's commitment to sourcing more renewable energy, traffic-congestion-reduction policies and air quality codes. Measuring quantitative and qualitative indicators together means the Indexes are based on current environmental performance as well as the city's intentions to become greener. It suggested seven steps to a Greener City: 1. Good governance and leadership at the metropolitan level, 2. A holistic approach, 3. Wealth is important, but at the early stages of development the right policies matter more, 4. Civic engagement, 5. The right technology, 6. The green and brown agenda need to go hand in hand, 7. Tackle informal settlements (EIU, 2012).

Venkatesh (2012) wrote a critique of the European Green City Index and opined that while adopting such performance evaluation methodologies, it is important to set targets and goals. The Green City Index needs to be considered together with an Urban Socio-Economic Index, which can be suitably structured with the inter linkage with the indicators of Green City Index. In 2014, Urban China Initiatives (UCI) published 'The China Urban Sustainability Index 2013' (UCI, 2014) which evaluated the level and potential of China's urban sustainability development using 23 indicators divided in 4 categories: Society, Environment, Economy, and Resources (weightage 33, 33, 17 and

17% respectively). Cleanliness and Built Environment were two components of Environment and were given equal weightage internally.

European Union published an in-depth report on ‘Indicators for Sustainable Cities’ (Science for Environment Policy—European Commission, 2015). It reviewed several scalable, easy to use indicator frameworks which have been summarised in Table 2.1

Table 2.1: Indicator frameworks and their characteristics

(Science for Environment Policy—European Commission, 2015).

Indicator Framework/Tool	Characteristics
China Urban Sustainability Index	It is a scalable tool developed for cities having population from 2 lakh to 20 lakh. The developed tool quantified urban growth and development.
City Blueprint	The developed tool consists of 24 indicators, subdivided into eight broad categories. The indicators were given a score on a scale of 0 to 10. More focus was given on resource use and least to governance and long-term sustainability.
European Economic Agency (EEA) Urban Metabolism Framework	A set of 15 indicators were chosen to monitor the urban metabolism in European cities. The framework is easy to use as the data can be easily gathered through available sources but the comprehensive solution to measure a city sustainability aspect was missing.
European Green Capital Award	It has been initiated in 2010 and reports are published every year for participating cities. The performance of the cities is judged on a set of 37 indicators which covers 9 nine categories of urban environmental sustainability. The participating cities should have at least 1 lakh population. The emphasis is given on improving the performance in the area of energy use and waste management.
European Green City Index	The developed tool evaluated 30 European cities on a set of 30 indicators of urban environmental sustainability. Health and improving quality of life were given less attention.
Global City Indicators Facility	The developed tool covers economic and social measures and ignored the third pillar (environment) of sustainability.
Indicators for Sustainability	The case study of different cities was examined and common indicators which were easy to be implemented and can cover a broad area of sustainability were chosen. Thus, the resultant indicator set is a flexible tool.
Reference Framework for	The developed tool consists of 16 key indicators and 300

Sustainable Cities (RFSC)	supplementary indicators, which covers economic, social, environment and governance. It gave special emphasis on sustainable governance and economic activity.
Sustainability Tools for Assessing and Rating (STAR) Community Rating System	The developed tool includes all the three pillars of sustainability: economic, social and environment. Emphasis was given to human wellbeing and quality of life.
Cities Statistics (Urban Audit)	The Urban Audit comprises of variables which can become indicator if information is provided on a particular issue. Urban audit database contains data which undergoes quality check and covers all aspects of urban sustainability in detail.
Urban Ecosystem Europe	The indicators chosen focussed more on local governance and quality of life. The tool developed is scalable as it evaluated cities having population range from 1.5 lakh to more than 2 million.
Urban Sustainability Indicators	The set of indicators selected was tested on European cities. The indicator set covers urban sustainability with special emphasis on environmental health.

As progress-measurement tools or static sustainability diagnostics, urban sustainability indicators provide simple, measurable evidence needed to create and maintain cities that are not just environmentally-friendly, but that promote long-term economic productivity, as well as the health and well-being of their citizens. Deng et al. (2019) presented a quick assessment methodology and applied it for evaluating sustainability in urban built environment of four large cities of China. Qualitative and quantitative approach was adopted for identifying sustainability dimensions and assigning their corresponding values. Equal weights of indicators under the same sub-division were adopted. The methodology was used to compare the performance of cities.

With a differing note, Ameen and Mourshed (2019) felt that most of the city development assessment framework took into account the priorities of the cities on global scenario, but the needs of developing countries were different. Accordingly, they developed an ‘Urban

Sustainability Assessment Framework’ for developing countries taking Iraq as the case study. The framework of Iraqi urban sustainability assessment framework (IUSAF) was compared to global framework. For the said purpose, weights were given to indicators by Analytical Hierarchy Process (AHP) and the study shows that the global assessment tools for developed countries and requirements for developing countries are markedly different. Due to political instability and deteriorated infrastructures in Iraq, ‘Water’, ‘safety’, and ‘transportation and infrastructure’ indicators were given high weighting scores compared to ‘well-being’ and ‘urban space’.

Thus, the reported literature suggests that although several frame works have been developed for sustainability assessment of cities in order to guide the decision makers, but the needs of developed and developing countries are different which is discussed in the later sections of this chapter.

2.2 Smart Cities

With development and application of Information and Communication Technology (ICT) and introduction of ‘smart targets’ in urban planning, the concept of ‘Smart Cities’ emerged around the year 1994 and they are basically cybernetically planned cities (Dameri and Cocchia, 2013). As noted by Komninos (2008), the notion of smart city is established from the combination of the knowledge society and digital city. It is defined as a “multi-layer territorial system of innovation” made up of digital networks, individual intellectual capital, and the social capital of the city, which together constitute collective intelligence. Economic competitiveness and innovation achieved through the knowledge-based economy marks a city as intelligent, allowing it to generate a “spatial competitive advantage” through industrial districts, regions, and learning clusters that produce sophisticated R&D and are supported by digital networks and artificial intelligence

(Komninos, 2008). Cohen (2012) presented a wheel model of smart cities (Fig. 2.1). This framework discussed six components of a smart city: Smart mobility (utilising the benefit of mobile service and clean urban mobility by means of ICT), Smart people (inclusion of citizen creativity and awareness to develop a sustainable city), Smart governance (transparency in the government services provided), Smart environment (improving the deteriorating climatic conditions by sustainable planning), Smart economy (entrepreneur skill and innovation), and, Smart living (being healthy and safe). This framework attempted to develop a universal model for all cities and presented a more technical description of smart city by covering broader range of spectrum.

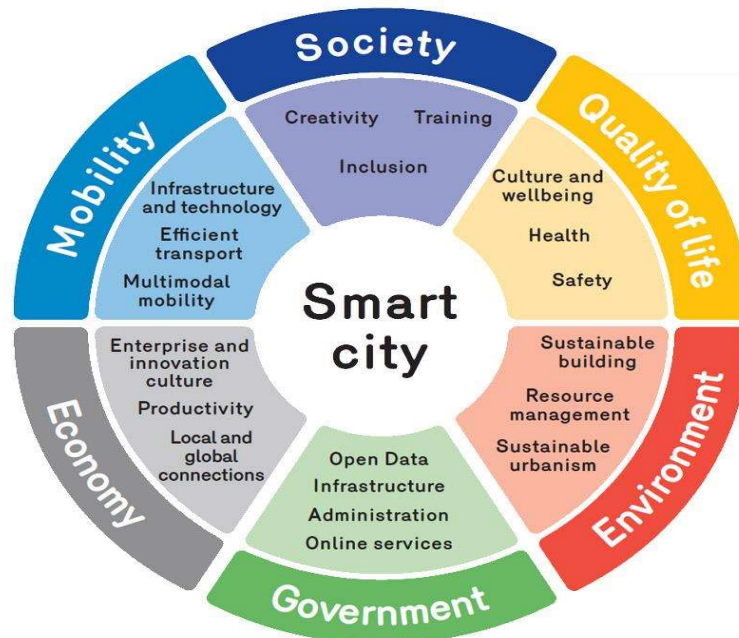


Fig 2.1: Wheel Model of Smart Cities (Cohen, 2012)

Joshi et al. (2016) considered that smart cities are an endeavour to make cities more efficient, sustainable and liveable. In other words, a smart city is a city that can monitor and integrate functionality of all the critical infrastructure like roads, tunnels, airways, waterways, railways, communication power supply, etc., control maintenance activities and can help in optimizing the resources while keeping an eye on the security issues as

well. To bridge the gap regarding the concept of smart cities and its implementation, a framework using six significant pillars: Social, Management, Economic, Legal, Technology and Sustainability (SMELTS) were developed (Fig. 2.2). It was observed that smart cities initiatives in the areas of technology, legal and economy have influence on social, management and sustainability aspects.

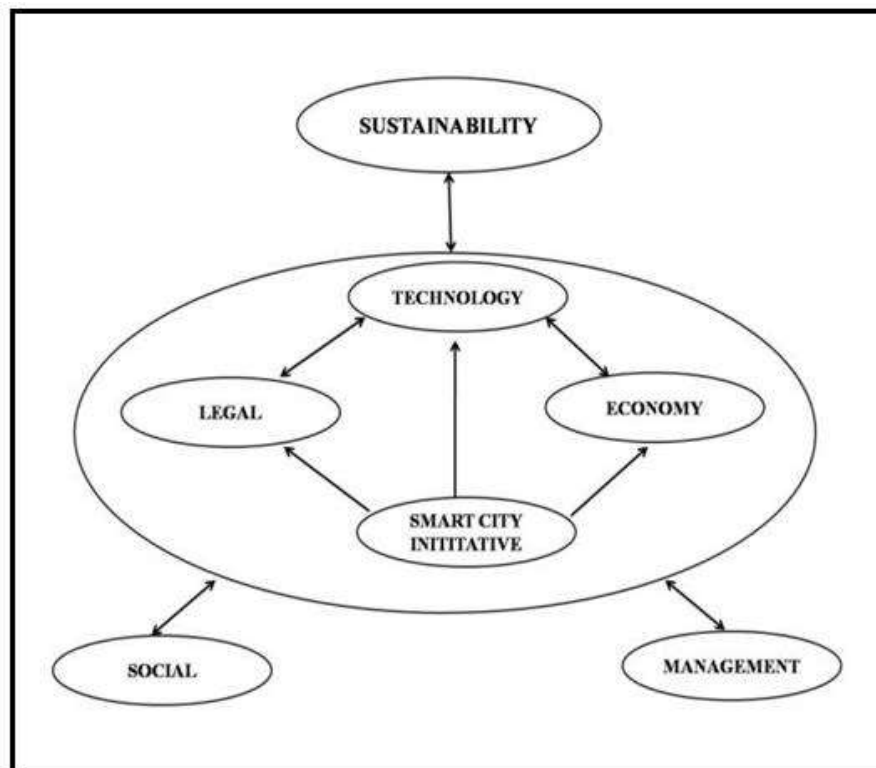


Fig 2.2: SMELTS Framework for Smart City Initiative (Joshi et al., 2016)

Sureshchandra et al. (2016) identified and ranked nine factors (Mobility/ Physical/ Innovation and learning/ Political/ Information, Communication and Technological/ Environmental/ Operational and Managerial/ Social/ and Economical) involving 66 indicators using Questionnaire survey and Significance Index Method for Smart Cities. Environmental Factor consisted of eight indicators: Availability of Natural resources, Greenhouse gas emission, Consumption of energy from renewable sources, Quality of resources, Environmental protection, Sustainable resource management, Biodiversity and Recycling of used resources. In addition, Water supply, Sanitation, Storm water

management and Solid waste management were grouped under Physical Factors. While Environmental factors ranked 6th among 9 factors considered, recycling of used resources, sustainable resource management and environment protection were found as three top ranking indicators in this group. Water supply, Sanitation and solid waste management were found as the priority ranking indicators in Physical facilities group of factors.

Based on ISO: 37120, Bureau of Indian Standard (BIS) developed Smart Cities Indicators: ICS 13.020.20. The indicators were divided into Core indicators (the essential criteria required for city) and Supporting indicators (representing the best practices implemented in the city). Environmental Indicators were considered under four sectors: Environment, Solid Waste, Sewerage and Sanitation, and Water Supply (Table 2.2)

Table 2.2: Smart Cities Environmental Indicators (BIS, 2016)

SECTOR	CORE INDICATOR	SUPPORTING INDICATOR
ENVIRONMENT	Fine Particulate Matter (PM _{2.5}) Concentration	NO ₂ (Nitrogen Dioxide) Concentration
	Particulate Matter (PM ₁₀) Concentration	SO ₂ (Sulphur Dioxide) Concentration
	Green House Gas Emissions Measured in Tones per Capita	O ₃ (Ozone) Concentration
	Air Quality Index	
	Noise Pollution	
	Quality of Public Water Bodies	
SOLID WASTE	Total collected municipal solid waste per capita	Percentage of the city's solid waste that is disposed of in a sanitary landfill
	Percentage of the city's solid waste that is recycled	Percentage of the city's solid waste that is disposed of in an Incinerator

		Percentage of the city's solid waste that is burned openly
		Percentage of the city's solid waste that is disposed off in an open dump
		Percentage of the city's solid waste that is disposed of by other means
SEWERAGE AND SANITATION	Percentage of city population having access to sanitary toilet facilities	Percentage of the city's waste water receiving secondary treatment
	Percentage of city population served by sewage (waste water) collection	Percentage of the city's waste water receiving tertiary treatment
	Percentage of the city's waste water receiving primary treatment	
WATER SUPPLY	Percentage of the city's waste water that has received no treatment	Total water consumption per capita (litres/day)
	Percentage of city population with potable water supply service	
	Total domestic water consumption per capita (litres/day)	Total water supply through metered water connections
		Average annual hours of water service interruption per household
		Percentage of water loss (Unaccounted for water)

Bosch et al., (2017) reported CITYkeys Indicators for smart city projects and smart cities. According to the authors, 'a smart city is a city that efficiently mobilizes and uses available resources (including but not limited to social and cultural capital, financial capital, natural resources, information and technology) for efficiently improving the quality of life of its inhabitants, commuting workers and students, and other visitors

(people); significantly improving its resource efficiency, decreasing its pressure on the environment and increasing resiliency [planet]; building an innovation driven and green economy (prosperity) and fostering a well-developed local democracy (governance). A total of 99 project indicators and 76 city indicators were defined for smart cities.

Indian School of Business (ISB) developed Smart Cities Index (SCI) for evaluating cities (ISB, 2017). The approach gives a framework for ranking of cities and calculation of Smart City Index. For easier understanding, a three-level hierarchy was created with Characteristic at the top level, Factor at the middle level and Indicators at the lowest level. Among six Characteristics (Living, Economy, People, Governance, Mobility and Environment) of smart cities considered at top level, environmental parameters were included in two characteristics: Living as well as Environment. Under Living Characteristics of a smart city, Water supply (Access to water supply, and Adequacy of water supply), Solid waste (Access to solid waste collection), Drainage (Coverage of storm water drains, Quality of storm water drainage facilities), Sewerage (Access to sewerage network, Sanitation (Access to household sanitation and Access to public sanitation) were considered as Factors (and Indicators). Under Environment characteristics, Air Pollution (PM2.5 concentration), Noise Pollution (L-EQ-Levels) and Sustainability (Sewage recycling, Solid waste recycling and Use of renewable energy) were considered as Factors (and respective indicators). The SCI used 58 indicators for six different characteristics and measured the quality of services of 53 cities with a population of more than one million. The authors ranked the cities based on Characteristics Index, Living Index, Mobility Index, Economy Index etc. as well as Smart Cities Index.

Rana et al. (2018) explored the barriers involved in Smart City Development in context to Indian scenario. 31 key barriers were selected through literature review which were divided into six categories: Governance (Lack of cooperation and coordination between city's operational networks, Unclear IT management vision, Political instability, Lack of trust between governed and government, Poor private-public participation, Lack of developing a common information system model) Economic (High IT infrastructure and intelligence deficit, Lack of competitiveness, Cost of IT training and skills development, Global economy volatility, Higher operational and maintenance cost) Social (Lack of involvement of citizens, Low awareness level of community, Geographical diversification problems, Degree of inequality) Technology (Lacking technological knowledge among the planners, Lack of access to technology, Privacy and security issues, System failures issues, Poor data availability and scalability) Environmental, (Lacking ecological view in behaviour, Growing population problems, Lack of sustainability considerations , Carbon emissions effect, Degradation of resources) Legal and Ethical (Cultural issues, Lacking standardization , Issues of openness of data, Lack of transparency and liability Lack of regulatory norms, policies and directions). The prioritization of the selected barriers is done through weighting technique fuzzy Analytic Hierarchy Process (AHP). The result revealed that Governance is the most significant barrier followed by 'Economic; 'Technology'; 'Social'; 'Environmental' and 'Legal and Ethical' for Smart City development.

The reported literature suggest that framework of sustainable cities strive to achieve sustainability goals and overlook smart solutions, whereas smart city focuses more on modern technologies and ICT. Thus, the key discrepancies of sustainable cities and smart cities should be identified and the framework should be restructured.

Cluster II

2.3 Differences between Sustainable Cities and Smart Cities

Table 2.3 presents the number of environmental indicators considered in some of the frameworks of Sustainable Cities and Smart Cities. It shows that Sustainable Cities frameworks include environmental indicators more than 50%, while the frameworks for Smart Cities gives priority to ICT and modern technological solutions. The weak connection between Smart Cities and environmental sustainability urges to reconstruct the framework for Smart Cities.

Table 2.3: Environmental indicators in Sustainable Cities and Smart Cities Frameworks

SUSTAINABLE CITIES			
Framework Reference	Total No of Indicators	No of Environmental Indicators	% Contribution of Environmental Indicators out of total
Organisation for Economic Co-Operation and Development (OECD,2001)	50 core indicators.	All the indicators related to integration of Transportation agriculture energy-environment).10 key environmental indicators related to air, water and natural resources.	100%
World Bank Environment Department (WBED) (Segnestam, 2002)	9	8	88%
Green City Index (GCI) (EIU, 2012)	30	19	63.33%
Urban Sustainability Index (USI) (UCI,2014)	16	10	62.5%
SMART CITIES			
Smart cities model (Lazaroiu&Roscia, 2012)	33	4	12.12%
Environmental Guideline For Smart Cities (MEM,2015)	26	7	26.92%
Assessment of critical	66	8	12.12%

success factors for Smart Cities (Sureshchandra et al.,2016)			
Smart Cities Indicators (BIS,2016)	93	28	30.10%
Smart Cities Index: A tool for Evaluating Cities (ISB,2017)	58	13	22.41%
CITYkeys indicators for smart city projects and smart cities (Bosch et al., 2017)	100	10	10%

Ahvenniemi et al., (2017) and also discussed the differences between sustainable cities and smart cities. They noted that in the 21st century, there has been a shift from sustainability assessment to smart city goals. After analysing 16 sets of city assessment frameworks (eight smart city and eight urban sustainability assessment frameworks) comprising 958 indicators altogether, and by dividing the indicators under three impact categories and 12 sectors, it was observed that as expected, there is a much stronger focus on modern technologies and “smartness” in the smart city frameworks compared to urban sustainability. While urban sustainability frameworks contain a large number of indicators measuring environmental sustainability, smart city framework lack environmental indicators while highlighting social and economic aspects. Thus, they noted that the frameworks developed for Smart Cities are not sufficient to attain environmental sustainability. Moreover, environmental indicators selected for Smart Cities framework are remarkably less compared to other domains: social, economy and governance. A general goal of smart cities is to improve sustainability with help of technologies. Thus, the authors recommended the use of a more accurate term “Smart Sustainable Cities” instead of smart cities. They further noted that the assessment of smart city performance should not only use output indicators that measure the efficiency of

deployment of smart solutions but also impact indicators that measure the contribution towards the ultimate goals such as environmental, economic or social sustainability.

2.4 Developed Countries Perspectives: From ‘Sustainable Cities’ to ‘Smart Sustainable Cities’

The International Telecommunication Union (ITU), the United Nations specialized agency for information and communication technologies (ICTs) defined ‘Smart Sustainable City’ (SSC) as “an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects” (ITU, 2014).

As is clear from the definition of SSC, the missing dimension of sustainability is being attempted to be added in the merits of Smart Cities. Accordingly, many researchers including Ahvenniemi et al. (2017) and Huovila et al. (2019) criticised the concept of Smart Cities because of being techno-centric and lack of environmental awareness. They felt that in the Smart Cities, the considerations of sustainability were outdated because of the need for a digitised city. They agreed to the emerging concept of ‘smart sustainable cities’ and felt that this combines urban sustainability and smartness emphasizing both aspects simultaneously. Its emergence can be seen both as a) a response to the critics of such smart city solutions that are contradictory to sustainability, and b) an attempt to address the needs of the currently highly digitalized cities more comprehensively than the traditional concept of sustainability. Huovila et al. (2019) also compared seven recently published indicator standards for smart sustainable cities (ISO:37120, ISO:37122, ETSI indicators, ITU 4910, ITU 4902, ITU 4903, UN SDG 11+ indicators) and developed a taxonomy to evaluate each of 413 indicators against five conceptual urban focuses (three

types of urban sustainability and two forms of smartness), ten sectoral application domains (e.g., energy, transport, ICT, economy, etc.) and five indicator types (input, process, output, outcome, impact).

The results of the analyses discriminated between indicator standards suited for evaluating the implementation of predominantly smart city approaches versus standards more focused on sustainability assessment.

2.5 Developing Countries Perspectives: From ‘Smart Cities’ to ‘Sustainable Smart Cities’

Smart Cities Mission of India aims to cope up with the massive urbanization challenges of the coming decades. The concept of the mission aims towards improving the quality of life by integrating technological solutions through ICT, which can be considered as sustainable development for the cities. But the mission appears weakly placed in addressing the environmental dimensions of sustainability. Especially in Indian contexts, Yadav et al. (2019) presented a structural framework to develop a sustainable smart city (SSC) for developing countries. The authors compiled a total of 33 ‘enablers’ of sustainable smart cities (SSC) and finalised the weights and ranking of 28 of them. Environmental Protection was one among the Social and Personal enablers, but got excluded from the SSC framework because of being placed in low intensity cluster suggested by the expert panel. This indicates that there is still a lack of sufficient awareness in the public about the need of environmental indicators in the context of Sustainable Smart Cities, where enablers of other components of sustainability (social and economic development) are out weighted than environmental.

Thus, there appears a definite need to develop a framework for Environmentally Sustainable Smart Cities (ESSC) in India and SCM implementation program can be taken as an opportunity to move towards such purposes.

Cluster III

2.6 Decision Support System (DSS) for Smart Cities

The use of Decision Support System (DSS) is rapidly progressing in the field of Smart Cities Management. Juan et al. (2011) proposed a DSS for planning and management of the cities in a smarter way by assessing the current situation of the cities and providing a set of improvement strategies with the help of hybrid approach called GAA*, which combines an A* graph search algorithm with genetic algorithms (GA) and is used to analyze all possible improvement strategies, budgets and determining optimal solutions. Two types of decision scenario have been provided in this model: Budget priority and Smart level priority, which will be demonstrated by policymakers to analyse the decision-making of DSS when subjected to the real-world conditions. In the Budget priority scenario, policymakers specify the budget and then optimise the technology selections within the limited cost. Three types of assessment are done for the Budget level priority. First of all condition assessment is done in which existing smartness level of the city is evaluated based on the criteria (Air quality, Energy production and conservation, Green built Environment, Waste and recycling, Water quality and conservation and Transportation). Secondly preference assessment is done in which budget range is specified for improving the smart level of the city. The priority of each criterion is determined by weighting technique known as Analytic Hierarchy Process (AHP). The third procedure is the system operation in which optimisation technique GAA* is used to determine the technology within the limited budget. In the Smart level priority scenario, the smart level of city is specified and then cost minimisation is done to achieve the

target. The procedure adopted for condition assessment is same in both the priorities. In the preference assessment the expected smart level of criterion is specified and AHP is used to decide the priority. In the system operation GAA* is used to determine the optimal combinations of technology selections that reach the smart level target with maximum benefit and minimum cost. In the entire assessment 55 indicators has been taken for 6 criteria, and the score allotted is 100. Higher score indicates that the existing condition is more satisfactory. Hybrid approach used in the developed model can be effective in dealing with complicated problems of achieving the target of smartness. Another DSS for Smart City components was developed by Bartozzoli et al. (2015) through integrating Analytical Hierarchical Process (AHP) with the Italian Flag (IF) representation. The proposed model can evaluate the data related to Smart Cities, determine the IF values which leads to the final determination of values for decision making process. In this model firstly the problem is analysed and a hierarchical tree is created in which lower nodes denotes the sub-criteria, the nodes at first level represent decisional criteria and the top represents the goal. Further, priority weights are allotted to each node by comparing the pair wise comparison matrices using Saaty's scale. The IF model measures the uncertainties in the proposed DSS. The model can be used by multiple users and can gather different data related to Smart City Environment. Miles et al. (2018) developed the DSS which analyse the various mitigation strategies to reduce atmospheric pollution in Smart Cities. It detects the critical level and prevents the atmospheric pollution to reach at that level by informing decision makers the time and place for the mitigation treatment to be implemented. The objective of the developed model is to assess mitigation strategies and the effect on reducing pollution levels, and monitor the air quality with IoT and fusing data ingested from multiple heterogeneous data sources. The input used for atmospheric model was an underlying traffic model

which predicted levels of atmospheric pollution due to traffic and change in the levels when mitigation strategies are implemented. The methodology utilises the DSS in which six stages are included (i) Detect if an area exceeds the critical atmospheric pollution level (ii) Identify latitude and longitude of the critical area (iii) Find the road that has the highest volume of traffic that is both upwind and within a specified distance of the critical area (iv) Decide on a mitigation strategy to implement (v) Implement the mitigation strategy and (vi) Exclude the critical site from immediate future analysis so that the treatment has time to work. As new areas of high pollution are detected, the DSS repeats these six steps. The proposed DSS can be used for different locations and can be generalised for all cities.

The topical studies show that DSS, IoT and Big data applications in context to Smart cities are used for improving economic growth and quality of life, without acknowledging the environmental sustainability (Bibri, 2018). This shows that there exists an earnest need to develop software applications in order to move towards Environmentally Sustainable Smart Cities (ESSC).

2.7 State of the Art and Challenges in the area of Smart Cities development

Huovila et al. (2019) criticized the concept of Smart Cities due to a lack of environmental awareness and being techno-centric, whereas sustainability was outdated because of the need for a digitized city. Yadav et al. (2019) presented a structural frame work for Sustainable Smart Cities (SSC) especially in the context of Indian cities and observed that environmental enablers are placed weakly than social and economic enablers of sustainability. Bibri (2018) observed that Decisions Support System (DSS), IoT and Big data applications are used extensively in the contexts of Smart Cities for improving

economic growth and quality of social life, without much acknowledgement of environmental sustainability.

Indian Government launched Smart Cities Mission (SCM) in July 2015 for developing 100 Smart Cities in the country in the first phase. Many cities of other developing countries are working for providing and maintaining modern infrastructure for roads, power plants, water treatment plants, sewerage and sewage treatment systems etc. Since such built environment lasts a long time, getting the right infrastructure in place shapes the future of the city for several decades to come. Planning a city with the right infrastructure, learning from the past mistakes and making them sustainable for long terms remain the objective.

While the developed countries are planning and developing ‘Smart Sustainable Cities’ (ITU, 2014, Houvila et al., 2019) after working on ‘Sustainable Cities’ and ‘Smart Cities’, in the developing countries Smart Cities Mission (SCM) of India is serving as a nodal point to work towards ‘Sustainable Smart Cities’ (Yadav et al., 2019). However, at present, the concept of ‘Sustainable Smart Cities (SSC)’ is just emerging and Smart Cities are being planned and developed with less than desirable emphasis on environmental dimension of sustainability (e.g. Bibri, 2018). Thus, there are suggestions to plan and develop ‘Environmentally Sustainable Smart Cities (ESSC)’ (Singh et al., 2020).

A comprehensive overview of the available literature in the field of ‘smart cities’ and ‘sustainable cities’ provides following observations:

- i) Sustainability is an essential condition of planning Smart Cities. However, even in the ‘Sustainable Smart Cities’ approach, out of the three pillars of sustainability, social and economic dimensions overweigh the environmental indicators in development.

- ii) The concept of Smart Cities is criticised due to lack of environmental awareness and being techno-centric.
- iii) The Internet of Things (IoT) and related applications has been used to improve the social conditions and economic growth, but ignores the environmental sustainability in context to smart cities.
- iv) In India, the development plans and programs implemented before 2015, generally lacked ‘environmental sustainability’ as an included objective.
- v) At present, there is no framework available for ‘Environmentally Sustainable Smart Cities’.

Thus, there appears a definite and urgent need to understand and formulate holistic framework for developing ‘Environmentally Sustainable Smart Cities (ESSC)’ for our conditions. Considering environment consisting of domains such as Solid Waste Management (SWM), Water Supply Management (WSM), Sewerage, Sanitation and Storm water (SSS) Management and Ambient Environment Condition (AEC) and identification of appropriate indicators for each categorised domain is needed. Accordingly, weight allocation of indicators should be carried out to reflect the relative importance of indicators. Further, benchmarking is needed for assessment of existing and target conditions. Thereafter, a Decision Support System for Environmentally Sustainable Smart Cities (DSS-ESSC) may be developed, which can be used as a decision-making tool for sustainable development and growth of Smart Cities. Research Methodology adopted for development of holistic framework considering all such issues is discussed in the next chapter.