Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

p-ISSN: 0972-6268 e-ISSN: 2395-3454	Vol. 19	No. 1	pp. 201-210	2020

Original Research Paper | Open Access

Selecting Environmental Indicators for Sustainable Smart Cities Mission in India

Prabhat Kumar Singh, Shruti† and Anurag Ohri
Department of Civil Engineering, Indian Institute of Technology (BHU), Varanasi-221005, Uttar Pradesh, India
†Corresponding author: Shruti

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 15-06-2019
Accepted: 23-07-2019

Key Words:
Smart cities
Sustainable cities
Environment decision support system (EDSS),
Environmental indicators

ABSTRACT

Government of India (GOI) initiated Smart Cities Mission in June 2015. In order to guide the process, evaluate the performance, and finally move towards making a Sustainable Smart Cities program, the objective is to develop software based Environmental Decision Support System for Sustainable Smart Cities in India (EDSS-SSCI). Identification and finalization of indicators to be used in the framework for evaluation of Sustainable Smart Cities in Indian context is the objective of the present study. The analyses indicate that Smart Cities Mission guidelines of GOI include 14 performance parameters related with environment, out of which 11 qualify the criteria required for being considered as environmental indicator as per World Bank Environment Development (WBED) considerations and 3 of them do not meet the requirements in terms of clarity of design and quantification for development costs. Further, a set of 20 additional environmental performance indicators are identified from the available literatures on requirements of Sustainable Cities, many of which are generally used as monitoring parameters in various programs of GOI. Subjecting these 20 additional indicators for suitability as environmental indicators based on WBED criteria and City Key Indicators criteria, results in finalizing a set of 13 indicators which meet all requirements and qualify to be used in development of framework for EDSS-SSCI. 10 of these indicators are already part of monitoring programs of Ministry of Urban Development (MoUD), 2 have been suggested by Bureau of Standards (BIS 2016) and 1 considered important by Japan International Corporation Agency (JICA 2016). Thus, taking 11 environmental indicators from Smart Cities Mission Guidelines and 13 selected indicators for Sustainable Cities, a total of 24 environmental indicators are finalised to be used in the framework of EDSS-SSCI for benchmarking, performance evaluation and guiding the investment plans for most effective resource utilization under Indian conditions.

INTRODUCTION

Rapid growth of urbanisation has taken place over the years in India. As per available records, there were 5161 classified towns and 384 urban agglomerations in the country in 2001, which increased to 7935 classified towns and 475 urban agglomerations in 2011 (Khadke et al. 2018). This massive growth made India the second largest urban system in the world (Abbu et al. 2015). According to UN Report, India is estimated to add 300 million more urban residents by 2050 to its existing 377 million populations. In July 2015, Ministry of Urban Development (MoUD), Government of India (GOI) announced the program for developing 100 Smart Cities in the country with emphasis on use of technologies to convert existing cities into Smart Cities to face the challenge of accommodating the needs of growing population (MoUD 2015).

The philosophical background of Smart City may be seen in the 'hierarchy of needs' given by great psychologist Abraham Maslows in 1943. It says that human motivations move through five levels of needs as shown in the pyramid (Fig.1). The physiological needs, such as clean air, healthy food, pure water, shelter etc. are the first level of requirements as they are the basic components for human survival. The humans cannot prosper unless these physiological needs are fulfilled. Safety and security needs, which include health and employment are the next level of requirements. Family, affection, belongingness constitutes the third level of human needs. As such, Smart Cities Mission in its current form has been targeted to achieve up to the second level of human needs.

It is common to understand that the conditions of each city differ from other; hence the meaning of smartness may also change from one situation to another. In larger perspective, parameters of a Smart City depend upon its current development level, available resources and the willingness of people to change for the decided objectives.

Application of information and communication technology (ICT) in the city development program is the core feature of Smart City initiatives. As noted by Lazaroiu & Roscia (2012), "Smart City" is a city, well performing in 6 characteristics: smart people, smart governance, smart living, smart

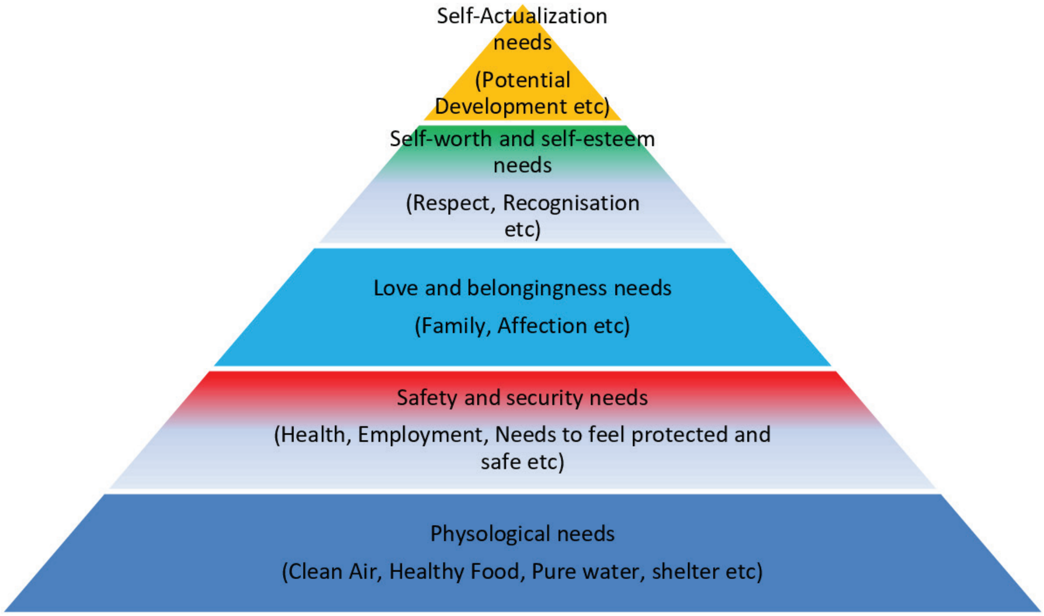

Fig. 1: Maslow's hierarchy of needs (Maslow 1943).

environment, smart economy and smart mobility. These six characteristics are the smart combination of activities and endowments of citizen awareness. As many cities of Europe and other parts of the world have been working towards 'Sustainable Cities' since past several decades, there is a renewed impetus to add smartness in the program using ICT. Thus, there are several definitions for "Smart Sustainable Cities", based on specific conditions and objectives of the program. On the other hand, there has been no specific sustainability focused City Development Plan in India. Smart Cities Mission is a major initiative by the Government to reinforce the urban life to face the growing challenges. Hence, planning towards "Sustainable Smart Cities" may be just required and appropriate for the country.

The International Telecommunication Union (ITU 2014) gave a comprehensive definition of Smart Sustainable City as 'a novel city which uses ICTs for urban services delivery and improving the quality of life, without compromising the needs of the present and future generations. Höjer & Wangel (2015) states that 'a Smart Sustainable City is a city that meets the needs of its present inhabitants without compromising the ability for other people or future generations to meet their needs, and thus, does not exceed local or planetary environmental limitations, and where this is supported by ICT.' Bibri & Krogstie (2017) summarised that a Sustainable City improves environmental quality by adopting sustainable development strategies for innovation and advancement. Sustainable cities optimize the use of its resources with reduced pollution and zero-waste system to promote liveability. But sustainable cities overlook smart solutions, i.e. the use of ICT which is the characteristic of Smart Cities. For cities to foster sustainability they should incorporate smart targets and Smart Cities should be in line with the vision of sustainability. Thus, there is emphasis towards "Smart Sustainable City" in developed parts of the world. In contrast, the focus of Indian Smart Cities Mission is on the use of ICTs and providing technology-based solutions to urban challenges, thus sustainability is not the objective part of program. Under the condition, planning and motivating for 'Sustainable Smart Cities' in India appears very much timely and desirable for long term benefits from the infrastructure developed and investment made. The objective of the present study is to select environmental indicators applicable in the framework of 'Sustainable Smart Cities', which can be used for evaluation and guidance of initiatives for long term sustainability and maximum environmental benefits.

SMART CITIES MISSION (SCM) IN INDIA

Smart Cities Mission (SCM) in India was launched in June 2015. Guidelines have been proposed by the Ministry of Urban Development (MoUD 2015) to highlight the requirements for development of a smart city. SCM is a bold initiative by the government to reduce the urban service de-

Table 1: Environmental indicators in smart cities mission of government of India.

Environmental Component	Indicators (Smart solutions+ Essential features)
A. Solid Waste Management	1. Waste to energy and fuel
	2. Waste to compost
	3. Recycling and reduction of construction and demolition waste
	4. Solid waste management programs carried in the city during last 3 years
B. Water Supply Management	5. Smart meters and Management
	6. Leakage identification
	7. Water quality monitoring
	8. Adequate water supply
	9. Extent of cost recovery in water supply services
C. Sewerage and Sanitation	10. Coverage of toilets
	11. Waste water recycling
	12. Extent of cost recovery
D. Storm Water Drainage	13. Storm water reuse
E. Pollution	14. Improvement in air quality

ficiencies and focuses towards making the cities sustainable and inclusive. The launch of SCM has brought an optimistic approach among decision-makers and had attracted financial investors. The core infrastructure development through SCM in Indian scenario comprises of 10 features: i. Adequate water supply of 24×7, ii. Assured electricity supply, iii. Sanitation, iv. Urban mobility, v. Affordable housing, vi. ICT and digitalization, vii. e-governance, viii. Sustainable environment, ix. Security, safety, and good health and, x. Compulsory education for all (MoUD 2015).

Smart City needs to create an approach towards socially inclusive communities with a low ecological imbalance (MEM 2015). Accordingly, environmental sustainability must be of greater importance along with other indicators in a Smart City. Thus, a wider model of City Development Plan including elements of environmental sustainability along with information-communication technology (ICT) appears desirable to be adopted for Smart Cities Mission in India. The environmental indicators included in the present SCM guidelines are as given in Table 1.

Need of a Framework for ‘Sustainable Smart Cities’ in India

European cities, which have been working in this direction since many years and have taken initiatives in various forms, such as green cities, eco- cities, sustainable cities and alike are desirous to include ‘smartness’ through application of ICT in urban infrastructure and services systems. However, in India, although several city development plans and programs have been implemented so far, ‘environmental sustainability’ has not been an included objective (Randhawa et al. 2017). Hence, the Smart Cities Mission, which is a focussed 5 years (2015-20) program, may be taken as an opportunity to plan and develop models of ‘Sustainable Smart Cities’ for the country which may serve as examples for smaller towns to follow and grow in the given socio-economic environment.

It is proposed to develop an Environmental Decision Support System for Sustainable Smart Cities in India (EDSS-SSCI) to be used as a decision-making tool for sustainable development and growth of Smart Cities. It may also help in strategic planning especially in the context of policy decisions for investment in city infrastructure development. The first step towards developing this tool is the selection of indicators, which are commonly monitored under various plans of the Government and may be used as parameters of sustainability and smartness with improving social infrastructure and increasing investments.

The key functional role of the indicator is to reduce the information complexity being conveyed to the decision makers. The indicators should be precise, measurable and independent. It should not be affected by other factors leading to ambiguous results. Data availability is major challenging task while selecting the indicators. The data should be easily gathered from Government reports, public sources, interviews, or from observations. Data which are expensive to obtain or needs extensive calculations (such as carbon footprint indicators) should not generally be included. Non-availability of data affects the overall result of index developed. Thus, there is a need to enlist the usable indicators and prepare a framework for evaluating the improvements in quality of life with developing infrastructure.

Selection of Environmental Indicators for Sustainable Smart Cities

The 14 environmental indicators included in the MoUD (2015) guidelines for Smart Cities Mission of Government of India were tested for their appropriateness based on World Bank Environment Development (WBED) 2002 criteria (Segnestam 2002). Six criteria used to decide the appropriateness of indicators are: (i) Direct relevance to objectives (ii) Direct relevance to the target group (iii) Clarity in design (iv) Realistic collection or development costs (v) High quality and reliability (vi) Appropriate spatial and temporal scale (Segnestam, 2002). Table 2 summarises the appropriateness of indicators used in Smart Cities Mission of GoI based on WBED (2002) criteria. It is observed that 11 indicators fully satisfy all the six criteria of WBED (2002). However, three indicators (A.1, A.2 and D.13) do not fully meet the appropriateness criteria fully. It is observed that the indicators A.1: Waste to energy and fuel, and A.2: Waste to compost do not meet the requirements of appropriateness in terms of clarity in design and realistic collections or development costs. The Smart Cities Mission guidelines does not have a target-based plan on these areas. However, in Swachh Bharat Mission (MoUD 2017) the degree of waste treatment is measured in terms of decreasing amount of waste going to landfill. If a city manages to dispose less than 20% of its total solid waste generated to landfills, it gets the highest score of 45 and if the waste going to landfill is more than 20%, it gets zero score. From this, it is may be inferred that in Smart Cities, 80% or more of the total

Table 2: Appropriateness of environmental indicators used in smart cities mission of GOI based on WBED (2002) Criteria.

Environmental Indicators	WBED (2002) Criteria(Segnestam 2002) (i) Direct relevance to objectives	(ii) Direct relevance to the target group	(iii) Clarity in design	(iv) Realistic collection or development costs.	(v) High quality and reliability	(vi) Appropriate spatial and temporal scale	% of compliance out of six criteria
A. Solid Waste Management							
1.Waste to energy and fuel	✓	✓	×	×	✓	✓	66.6%
2.Waste to compost	✓	✓	×	×	✓	✓	66.6%
3.Recycling and reduction of construction and demolition waste	✓	✓	✓	✓	✓	✓	100%
4. Solid waste management programs carried in the city during last 3 years.	✓	✓	✓	✓	✓	✓	100%
B. Water Supply Management							
5.Smart Meters	✓	✓	✓	✓	✓	✓	100%
6.Leakage identification	✓	✓	✓	✓	✓	✓	100%
7.Water quality monitoring	✓	✓	✓	✓	✓	✓	100%
8.Adequate water supply	✓	✓	✓	✓	✓	✓	100%
9.Extent of cost recovery in water supply services	✓	✓	✓	✓	✓	✓	100%
C. Sewerage and Sanitation							
10.Coverage of toilets	✓	✓	✓	✓	✓	✓	100%
11.Waste water recycling	✓	✓	✓	✓	✓	✓	100%
12.Extent of cost recovery	✓	✓	✓	✓	✓	✓	100%
D. Storm Water Drainage							
13.Storm water reuse	✓	✓	×	×	✓	✓	66.6%
E. Pollution							
14. Improvement in air quality	✓	✓	✓	✓	✓	✓	100%

organic waste generated should be targeted to be processed for energy conversion or composting. With a clear mention of proportion of waste planned to be converted to energy or fuel (A.1) and waste to fertilizer as compost (A.2), these two environmental indicators included in SCM guidelines may also qualify as appropriate as per WBED (2002) criteria. The indicator D.13: Storm water reuse does not fulfil the criteria in terms of clarity in design and realistic collection. In line with environment guidelines of Mauritius, (MEM 2015), if achievable targets with probable cost of storm water reuse such as toilet flushing, car washing, garden irrigation etc. are defined in Smart Cities Mission monitoring program, this indicator may also be considered appropriate. In cases where cities report groundwater depletion, ground water recharge through storm water reuse may be an option. Till the time these parameters are made objective and target based, in the present form they cannot be considered appropriate indicators for measuring environmental sustainability of the proposal. Hence, these three indicators are not included in the proposed framework for Sustainable Smart Cities.

Additional Indicators for Sustainable Cities and Evaluation of Their Appropriateness

From the perspectives of environmental sustainability, apart from 14 indicators included in the Smart Cities Mission Guidelines (Table 1), 20 additional indicators were screened from available literature on Sustainable Cities (Table 3). Significantly, these indicators have largely been considered important are being used as monitoring parameters in different plans of Government of India. Appropriateness of these additional 20 indicators screened from available literature for Sustainable Cities have been examined similarly based on WBED (2002) criteria, as given in Table 4. It is observed that among these 20 indicators, 4 do not fully meet the requirements of criteria for being considered appropriate. In the Smart Cities Mission, frequency of street sweeping per day has not been decided based on total amount of waste generation. Hence the indicator A.1: Street Sweeping may not be considered appropriate at this stage to be included as a measure of Sustainable Smart City framework design. A7: Availability of collection bin is considered inappropriate because for a smart city, zero bin concept is desirable objective. A.9: Availability of roadmap does not fulfil the requirements of appropriateness in terms of clarity in design. D.18: Incidence of water logging defined in the terms of number of times water logging reported per year does not give the clear picture in terms of percentage of area flooded with respect to the total area of the city. Hence, this indicator also does not provide clarity in design and hence may not be considered appropriate to be included in the framework. The remaining 16 indicators which fulfil the WBED (2002) criteria for appropriateness were further tested on criteria given by City Key Indicators (Bosch et al. 2017)indicators have been selected that can function as Key Performance Indicators for tracking the progress towards city and project objectives. The indicators for assessing smart city projects serve to assess or evaluate single projects. They indicate the difference the project has made, by comparing the situation without the project with the situation after the implementation of the project. As such they can also serve to benchmark projects against each other. The indicators for smart cities focus on monitoring the evolution of a city towards an even smarter city. The time component -\u201cdevelopment over the years\u201d- is an important feature. The city indicators may be used to show to what extent overall policy goals have been reached, or are within reach. With a starting point in the smart city definition, and taking into account the wishes of cities and citizens with regard to smart city projects and indicators, the indicators are arranged in an extended triple bottom line sustainability framework, including the themes people, planet, prosperity, governance and propagation. Under the main themes subthemes conforming with major policy ambitions have been identified. Under these subthemes in total 99 project indicators and 76 city indicators have been selected. Not all indicators are equally suited for evaluating all types of smart city projects. Although there is a considerable body of common indicators, for specific sector projects a relevant subset of these may be used (i.e. some indicators are specifically suited for transport projects, other for building related projects, etc.. The criteria include (i) Relevance (ii) Completeness (iii) Availability (iv) Measurability (v) Reliability (vi) Familiarity (vii) Non-Redundancy and (viii) Independence (Table 5). In the evaluation process of appropriateness, the redundancy of the indicators needs to be examined with due care.

In planning a sustainable smart city, 100% coverage of collection of the solid waste appears essential. Hence, household coverage in terms of percentage of houses has been taken as redundant. Instead, efficiency of collection which is reflected in the sanitary and aesthetic environment of the city has been considered relevant. For water supply management, 'coverage of the area' is expressed in terms of total number of households with direct water supply connection in reference to the total number of households in the city. 'Adequate water supply' is expressed in the terms of total quantity of water supplied into the distribution system with respect to the total population of the city. Hence the first (coverage of area) is considered redundant. In the sewerage and sanitation sector, 'coverage of sewerage network' denotes the extent to which wastewater management facilities are available to individual properties across the city whereas 'collection efficiency' denotes the actual proportion of waste water generated in the city that is collected by the available sewerage network. Hence, former is taken as redundant for the purpose of preparation of this framework. After such scrutiny, out of the screened 16 indicators, a list of 13 indicators is finalized. With 11 environmental indicators found appropriate from the list of 14 included in the Smart Cities Mission program, and 13 selected from the requirements of environmental sustainability, all together these 24 indicators are finalised to be used in the framework of EDSS-SSCI (Table 6).

Data availability is important criteria for selection of indicators. For the indicators selected, the probable sources for data for different environmental management sectors such as Solid Waste Management, Water Supply Management and Sewerage, Sanitation and Pollution have been attempted to be compiled for Indian conditions. City Development Plan (CDP) and Swachh Sarvechhan Report (SSR) from the Swachh Bharat Mission program are found prominent sources of these data required for such indicators. Data about groundwater is normally available from reports of Central Groundwater Board (CGWB) of Government of India. Air quality and noise quality data can be obtained through Central Pollution Control Board (CPCB) and ENVIS sources respectively. Thus, the indicators selected are considered well supported with data from available sources for evaluation of a Sustainable Smart City.

CONCLUSIONS

The current guidelines for Smart Cities Mission (SCM) of Government of India include 14 environmental parameters: 4 under Solid Waste Management (A), 5 under Water Supply Management (B), 3 under Sewerage and Sanitation (C), and 1 each under Storm Water Drainage (D) and Pollution (E). When scrutinized on the criteria for appropriateness of an indicator, as suggested by World Bank Environment

Table 3: Additional environmental indicators required for sustainable cities.

Environmental Indicators	References for relevance
A. Solid Waste Management	
1) Street Sweeping	CPHEEO 2016; JICA 2016; MoUD 2017;Ministry of Urban Development (MoUD Garau et al. 2018
2) Household Coverage	CPHEEO 2016; MoUD 2012; MoUD 2017
3) Degree of Segregation	CPHEEO 2016; MoUD 2012; MOUD 2017
4) Efficiency in collection of MSW	BIS 2016; MoUD 2012; MoUD 2017
5) Extent of solid waste recovered	BIS 2016; EIU 2012; MoUD 2012
6) Degree of scientific disposal of MSW	BIS 2016; EIU 2012; MoUD 2012
7) Availability of collection bin at appropriate place at commercial and residential areas	Garau et al. 2018; MoUD 2017
8) Availability of roadmap for waste transportation of MSW as per Swachh city plan	MoUD 2017
9) Extent of cost recovery in Solid Waste Management services	MoUD 2012
B. Water Supply Management	
10) Coverage of water supply connections	MoUD 2012
11) Continuity of water supplied in terms of average number of hours per day	MoUD 2012
12)Identification of water sources and exploitation of underground water	JICA 2016 Howard et al. 2005
C. Sewerage and Sanitation	
13) Coverage of sewerage	BIS 2016; Dong et al. 2017
14) Collection efficiency of sewage network	MoUD 2012
15) Adequacy of sewage treatment capacity	EIU 2012; MoUD 2012
16)Quality of treated sewage	MoUD 2012
D. Storm Water Drainage	
17) Coverage of storm water drainage	MoUD 2012
18) Incidence of water logging	MoUD 2012
E. Pollution	
19) Noise pollution	Bosch et al. 2017 BIS2016
20)Quality of surface water bodies	BIS 2016

Table 4: Appropriateness of 20 additional environmental indicators for sustainable cities based on WBED (2002) criteria.

	Suitability of Indicator based on World Bank (2002) Criteria (Segnestam 2002)						
Environmental Indicators for Sustainable Cities	(i) Direct relevance to objectives	(ii)Direct relevance to the target group	(iii) Clarity in design	(iv) Realistic collection or development costs.	(v)High quality and reliability	(vi)Appropriate spatial and temporal scale	
A. Solid Waste Management							
1 Street Sweeping	✓	✓	×	×	×	✓	50%
2 Household Coverage	✓	✓	✓	✓	✓	✓	100%
3 Degree of Segregation	✓	✓	✓	✓	✓	✓	100%
4 Efficiency in collection of MSW	✓	✓	✓	✓	✓	✓	100%
5 Extent of solid waste recovered	✓	✓	✓	✓	✓	✓	100%
6 Degree of scientific disposal of MSW	✓	✓	✓	✓	✓	✓	100%
7 Availability of collection bin at appropriate place at commercial and residential areas	×	✓	✓	✓	×	✓	66.6%
8 Extent of cost recovery in	✓	✓	✓	✓	✓	✓	100%
9 Availability of roadmap for waste transportation of MSW as per Swachh city plan	×	×	✓	✓	✓	✓	66.6%
B. Water Supply Management							
10. Coverage of water supply connections	✓	✓	✓	✓	✓	✓	100%
11. Continuity of water supplied in terms of average number of hours per day	✓	✓	✓	✓	✓	✓	100%
12. Identification of water sources and exploitation of underground water	✓	✓	✓	✓	✓	✓	100%
C. Sewerage and Sanitation							
13. Coverage of sewerage	✓	✓	✓	✓	✓	✓	100%
14. Collection efficiency of sewage network	✓	✓	✓	✓	✓	✓	100%
15.Adequacy of sewage treatment capacity	✓	✓	✓	✓	✓	✓	100%
16.Quality of treated sewage	✓	✓	✓	✓	✓	✓	100%
D. Storm Water Drainage							
17.Coverage of storm water drainage	✓	✓	✓	✓	✓	✓	100%
18.Incidence of water logging	×	✓	×	×	×	✓	33.3%
E. Pollution							
19.Noise pollution	✓	✓	✓	✓	✓	✓	100%
20.Quality of surface water bodies	✓	✓	✓	✓	✓	✓	100%

Table 5: Appropriateness of environmental indicators for sustainable cities based on city key indicators criteria (Bosch et al. 2017)

	City Key Indicators criteria (Bosch et al. 2017)								
Sustainable City Environmental Indicators	(i) Relevance	(ii) Completeness	(iii) Availability	(iv) Measurability	(v) Reliability	(vi) Familiarity	(vii) Non-Redundancy	(viii) Independence	
A. Solid Waste Management									
1. Household Coverage	✓	✓	✓	✓	✓	✓	×	×	75%
2. Degree of Segregation	✓	✓	✓	✓	✓	✓	✓	✓	100%
3. Efficiency in collection of MSW	✓	✓	✓	✓	✓	✓	✓	✓	100%
4.Extent of solid waste recovered	✓	✓	✓	✓	✓	✓	✓	✓	100%
5.Degree of scientific disposal of MSW	✓	✓	✓	✓	✓	✓	✓	✓	100%
6.Extent of cost recovery in Solid Waste Management	✓	✓	✓	✓	✓	✓	✓	✓	100%
B. Water Supply Management									
7.Coverage of water supply connections	✓	✓	✓	✓	✓	✓	×	✓	87.5%
8.Continuity of water supplied in terms of average number of hours per day	✓	✓	✓	✓	✓	✓	✓	✓	100%
9. Identification of water sources and exploitation of underground water	✓	✓	✓	✓	✓	✓	✓	✓	100%
C. Sewerage and Sanitation									
10. Coverage of sewerage	✓	✓	✓	✓	✓	✓	×	×	75%
11.Collection efficiency of sewage network	✓	✓	✓	✓	✓	✓	✓	✓	100%
12.Adequacy of sewage treatment	✓	✓	✓	✓	✓	✓	✓	✓	100%
13.Quality of treated sewage	✓	✓	✓	✓	✓	✓	✓	✓	100%
D. Storm Water Drainage									
14.Coverage of storm water drainage	✓	✓	✓	✓	✓	✓	✓	✓	100%
E. Pollution									
15.Noise pollution	✓	✓	✓	✓	✓	✓	✓	✓	100%
16.Quality of surface water bodies	✓	✓	✓	✓	✓	✓	✓	✓	100%

Table 6: Finalized environmental indicators suggested for 'Sustainable Smart Cities' framework.

Indicators included in Smart Cities Mission (MoUD 2015)	Additional indicators desirable to be included for 'Sustainable Smart Cities' and their sources in India
A. Solid Waste Management	
1. Recycling and reduction of construction and demolition waste	1. Degree of segregation (MoUD 2012, MoUD 2017)
2. Solid waste management programs carried in the city during last 3 years.	2. Efficiency in collection of MSW (MoUD 2012, MoUD 2017)
	3. Extent of solid waste recovered (MoUD 2012)
	4. Degree of scientific disposal of MSW (MoUD 2012)
	5. Extent of cost recovery in Solid Waste Management (MoUD 2012)
B. Water Supply Management	
3. Adequate water supply	6. Continuity of water supplied in terms of average no of hrs per day (MoUD 2012)
4. Smart meters and Management	7. Identification of water sources and Exploitation of underground water (JICA 2016)
5. Leakage identification	
6. Water quality monitoring	
7. Extent of cost recovery in water supply services	
C. Sewerage and Sanitation	
8. Coverage of toilets	8. Adequacy of sewage treatment capacity (MoUD 2012)
9. Waste water recycling	9. Collection efficiency of sewage network (MoUD 2012)
10. Extent of cost recovery	10. Quality of treated sewage (MoUD 2012)
D. Storm Water Drainage	
	11. Coverage of storm water drainage (MoUD 2012)
E. Pollution	
11. Improvement in Air Quality	12. Noise Pollution (BIS 2016)
	13. Quality of surface water bodies (BIS 2016)

Development (WBED 2002), only 11 (2 under category A. 5 under B, 3 under C and 1 under E) are found suitable, while 3 are considered inadequately defined in terms of clarity or objective evaluation.

In order to propose and plan Smart Cities as 'Sustainable Smart Cities' in India, a set of 20 additional parameters are screened from available literature related with sustainable cities across the world. Out of these 20 additional parameters, only 16 could be found satisfying the requirements of appropriateness as indicator, as per WBED (2002) criteria. When these 16 indicators are further subjected to evaluation on 7 criteria, used by City Key Indicator program, only 13 (5 under category A, 2 under category B, 3 under category C, 1 under D and 2 under category E) are found fully satisfying the requirements as environmental indicators and 3 parameters are found to be inadequately defined. Accordingly, a set of 24 indicators are finalized (7 for Solid Waste Management, 7 for Water Supply Management, 6 for Sewerage and Sanitation, 1 for Storm Water Management and 3 under Pollution) which can be used in the scientific framework, named as Environmental Decision Support System for Sustainable Smart Cities in India (EDSS-SSCI) for evaluation and monitoring purposes. The sources of data under Indian administrative set up and programs have also been identified. On the lines of the indices developed for Smart Cities, the selected indicators are envisaged to be used to develop a Sustainable Smart Cities Index (SSCI) which may be used to assess the comparative performance of cities on the scale of smartness and sustainability with increasing investment and improving urban infrastructure.

ACKNOWLEDGEMENTS

All the necessary facilities for this work have been provided by the Indian Institute of Technology (Banaras Hindu University) Varanasi.

REFERENCES

Abbu, N., Kumar, E. and Saini, V. 2015. Urban green growth strategies for Indian cities. ICLEI-Local Government for Sustainability, South Asia (1).

Bibri, S. and Krogstie, J. 2017. Smart sustainable cities of the future: An extensive interdisciplinary literature review. Sustainable Cities and Society.

Bosch, P., Jongeneel, S., Rovers, V., Neumann, H.M., Airaksinen, M. and

Huovila, A. 2017. CITYkeys indicators for smart city projects and smart cities.

BIS 2016. Smart Cities-Indicators ICS 13.020.20.

CPHEEO 2016. Municipal Solid Waste Management Manual (12).

Khadke, P.A. and Waghmare, P.B. 2018. Class and size wise distribution of urban centre and their determinants in Maharashtra. Research Review. International Journal of Multidisciplinary and Current Research, 8(3): 722-730.

Dong, Y. and Hauschild, M.Z. 2017. Indicators for Environmental Sustainability. In Procedia CIRP, 61: 697-702.

EIU 2012. The Green City Index. The Economist Intelligence Unit (EIU), 25. Retrieved from http://aiph.org/wp-content/uploads/2015/04/Green City - Guidelines.pdf

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

Howard, G. and Bartram, J. 2005. Effective water supply surveillance in urban areas of developing countries. J. Water Health, 3: 31-42.

Höjer, M. and Wangel, S. 2015. Smart sustainable cities: Definition and challenges.In: L. Hilty & B. Aebischer (Eds.), ICT Innovations for Sustainability. Berlin, Springer-verlag, pp. 333-349.

ITU 2014. Agreed definition of a smart sustainable city, Focus Group on Smart Sustainable Cities, SSC-0146 version Geneva, 5-6 March.

JICA 2016. Republic of India Data Collection Survey on Improvement of Environment in Varanasi City, Republic of India Final Report (Main Report).

Lazaroiu, G.C. and Roscia, M. 2012. Definition methodology for the smart cities model. Energy, 47(1): 326-332.

Maslow, A.H. 1943. A theory of human motivation.Psychological Review, 50: 370-396.

MEM 2015. Cleaner greener and safer Mauritius, environmental guideline for smart cities. Ministry of Environment, Sustainable Development, and Disaster and Beach Management.

MoUD 2017. Swachh Survekshan 2017, A Guidebook for Urban Local Bodies.

MoUD 2012. Service levels in urban water and sanitation sector. Retrieved from http://mohua.gov.in/upload/uploadfiles/files/SLB%20National%20Data%20Book_0.pdf

MoUD 2015. Mission statements and Guidelines. Retrieved from http://smartcities.gov.in/upload/uploadfiles/files/SmartCityGuidelines(1).pdf

Segnestam, L. 2002. Indicators of Environment and Sustainable Development. World Bank Environment Development (WBED), Paper No. 89.

Randhawa, A. and Kumar, A. 2017. Exploring sustainability of smart development initiatives in India. International Journal of Sustainable Built Environment, 6(2):.701-710.