PREFACE

The Government of India (GOI) initiated Smart Cities Mission in June 2015. There is a growing consensus that the initiatives taken under Smart Cities Mission (SCM) in India should be used as an opportunity to prepare models for 'Environmentally Sustainable Smart Cities (ESSC)' for the developing world. While developed countries have earlier worked for 'Sustainable Cities' and are now moving towards 'Smart Sustainable Cities', the conditions in developing countries are moving from 'Cities' to 'Smart Cities' and then towards 'Sustainable Smart Cities'. SCM guidelines in its current form appear to emphasize more on social and economic development as well as governance issues using modern tools of Information and Communication Technology (ICT). Accordingly, the concept of Smart Cities is criticized due to a weak connectivity with the environmental sustainability quotient. Such conditions demand planning for 'Environmentally Sustainable Smart Cities (ESSC)' with an understanding that social and economic objectives are well engrained as part of being 'smart'.

In order to develop a system of evaluation for current conditions, and guide the process through benchmarking of services and attaining conditions of 'Environmentally Sustainable Smart Cities (ESSC)' in India, the overall aim of the present study is to develop a software-based Decision Support System for Environmentally Sustainable Smart Cities (DSS-ESSC).

Identification and finalization of indicators to be used in the framework for evaluation of Environmentally Sustainable Smart Cities in the given context is the first objective of the present study. The analyses indicate that SCM guidelines of GOI, in its present form includes 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 is identified from the available literature on the subject related with 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 CITYkeys indicators criteria results in finalizing a set of 13 indicators that meet all requirements and qualify to be used in the development of a framework for DSS-ESSC. Amongst them, 10 indicators are already part of monitoring programs of the Ministry of Urban Development (MoUD), 2 have been suggested by the Bureau of Indian Standards (BIS 2016), and 1 considered important by Japan International Corporation Agency (JICA 2016). Thus, taking 11 environmental indicators from Smart Cities Mission Guidelines of India and 13 selected indicators for Sustainable Cities perspectives, a total of 24 environmental indicators are finalized to be used in the framework of DSS-ESSC. The proposed DSS-ESSC is a user-friendly tool that can be easily accessed on url smartcitydss.pythonanywhere.com. The application evaluates a city's performance on a set of 24 selected environmental indicators, broadly grouped under four domains: Solid Waste Management (SWM), Water Supply Management (WSM), Sewerage, Sanitation and Storm water Management (SSS), and Ambient Environment Condition (AEC).

A model has been developed to arrive at a 'Smart City Environmental Sustainability Index (SCESI)' which is the second objective of the study. It is developed on a 0-100 increasing scale, and based on decreasing SCESI value, the city's environmental sustainability have been classified under 5 categories: Excellent (>80), Good (60-80), Fair (40-60), Poor (20-40) or Critically Low (<20).

The entire process of reaching SCESI value is done in four steps: i. Selection of Indicators for Environmentally Sustainable Smart Cities, ii. Assigning weights for the indicators, iii. Benchmarking of selected indicators and iv. Calculation of Smart City Environmental Sustainability Index (SCESI). All domains have been considered equally important.

Indicators within a domain have been assigned differential weights based on Delphi Technique. Benchmarking is done for each of the finalized indicators based on best attainable standards. Benchmarked Indicator Value (BIV) of each indicator is obtained on 0 to 100 convertible scale and classified into 4 categories: Excellent, Good, Average, and Poor. Using the weight of the indicator and the benchmarked indicator value (BIV), Indicator Score (IS) is obtained, which can be used to understand the current environmental position of the city with respect to that indicator. This can be used as a tool for identification of areas of urgent attention and investment for improvements and maximum environmental gains which is the third objective of the study. Summation of indicator scores (ISs) gives respective domain indices (DIs). SCESI is the arithmetic mean of four DIs: SWMI, WSMI, SSSI and AECI.

For test check of applicability and interpretation of results using this framework, five cities of India, which are currently being developed under SCM (Delhi, Patna, Allahabad, Varanasi, and Bhubaneswar), have been examined. The analyses indicate that while three of them (Delhi, Allahabad, and Bhubaneswar) are found in Fair (SCESI=40-60) category of environmental sustainability, two (Varanasi and Patna) are in Poor (SCESI=20-40) category. Comparing 4 DIs (SWMI, WSMI, SSSI, AECI) for each of the 5 selected cities (Total 20 DIs), 2 are found in Good (SSSI and AECI for Allahabad), 11 in Fair (SWMI for Delhi and Bhubaneswar; WSMI for all 5 selected cities; SSSI for Delhi and Varanasi; AECI for Patna and Bhubaneswar), 5 in Poor (SWMI for Patna, Varanasi, Allahabad; SSSI for Patna and Bhubaneswar) and 2 in Critically Low (AECI for Delhi and Varanasi) categories of environmental sustainability.

For policy makers, it is advisable to prioritize environmental domains under Critically Low (CL) and Poor (P) categories to attain ‘Fair’ conditions sequentially with judicious distribution of funds for stepped improvements. Attaining ‘Good’ category is the minimum

target for all the domains. Thus, Ambient Environment Condition (AEC) is found under Critically Low (CL) category for Delhi (AECI= 11.40) and Varanasi (AECI= 12.40). Similarly, Solid Waste Management (SWM) is found under Poor category for three cities: Allahabad, Varanasi and Patna (SWMI= 20.70, 20.70 and 25.70 respectively) whereas and Sewerage, Sanitation and Storm water Management (SSS) is under Poor category for Patna and Bhubaneswar (SSSI= 39.52 and 35.00 respectively).

For time bound planning, a target-based approach may be followed for improving the existing environmental conditions, particularly for domains under Critically Low (CL), Poor (P) and 'Fair' categories. Accordingly, a phased intervention plan of 5 years (first three years followed by next two years) has been suggested to achieve the target of Environmentally Sustainable Smart Cities in the country. Once a 'Good' level of environmental domain sustainability and overall SCESI (>60) are attained, further improvements may be targeted for better quality of urban life. Thus while maintaining and further improving other domains, AEC followed by SSS should be the priority domains for Delhi; SWM and SSS for Patna; AEC followed by SWM for Varanasi; SWM followed by WSM for Allahabad; and SSS followed by AEC for Bhubaneswar.Analyses and study of indicator scores (ISs) suggest that ambient sound level reduction followed by surface water quality management in Delhi and Varanasi; wastewater recycling in Bhubaneswar; improving degree of segregation under SWM for Allahabad and scientific disposal of MSW in Patna are the most urgent priority actionsto improve the environmental conditions.

The analyses indicates that the framework developed for evaluating environmental sustainability of a smart city through Smart Cities Environmental Sustainability Index (SCESI) appears giving justifiable and acceptable results. Thus, as an extension of application, 10 additional Indian cities under current SCM list from different zones of the country representing varying climatic conditions (Jaipur, Agra, Kanpur, Lucknow,

Muzaffarpur, Agartala, Vishakhapatnam, Bangalore, Surat and Indore) were selected for studying the possible wider use of developed DSS-ESSC and SCESI. The results indicated that SCESI of Vishakhapatnam, Bangalore, Surat and Kanpur fall in 'Fair' category, while Muzaffarpur, Agartala, Jaipur, Agra and Lucknoware found in 'Poor' category. The only city that manages to secure 'Good' category is Indore.Accordingly, domains of priority and areas of urgent interventions and improvements under 5 years phased development program can be identified.

Overall, the present study puts forward a frame work for understanding and evaluating the environmental sustainability of Smart Cities under development in India. The software based DSS-ESSC application and model for calculating 'Smart Cities Environmental Sustainability Index (SCESI)' may be used as a monitoring and diagnostic tool for planning and management of services connected with environmental dimension in the city life. The application may also be used for performance evaluation and decision-making tool for identification of priority areas for actions and investment in Smart Cities development in line with the vision of ensuring environmental sustainability.