

1.1 Growth of Cities in India

Urban population in India increased from 11.4 % in 1901 to 28.53% in 2001 and stood at around 34 % of total in 2017 (The World Bank Data, 2019). According to a survey by United Nations (UN), 40.76% of country's population is expected to reside in urban areas by 2030. In general, rapid urbanization worldwide has created sheer pressure on the urban built environment (Turner, 1990). As per the census report 2001, there were 5161 classified towns and 384 urban agglomerations in India, which increased to 7935 classified towns and 475 urban agglomerations in 2011 (Khadke and Waghmare, 2018). India's urban population is expected to reach 814 million by the year 2050 and will become the second most populated country globally (Randhawa and Kumar, 2017). Due to the rapid increase in urbanization rate, the number of megacities in India (Bangalore, Delhi, Mumbai, Kolkata, and Chennai) will increase from 5 to 7 by 2030, with the new addition of Ahmadabad and Hyderabad (Randhawa and Kumar, 2017). The massive urbanization growth will provide new employment and contribute to 70% of India's GDP by 2030 (Sankhe et al., 2010). However, the population growth in the urban sector will also lead to environmental degradation, lack of resources, congestion and destruction of habitats, etc. Consequently, the life of a city-dweller will become arduous unless the development of physical (e.g., Water Supply, Sewerage, Solid Waste, etc.), institutional (such as Law enforcement, Security, etc.), social (Education, Healthcare, Inclusive planning), and economic (GDP, Livelihood activity, etc.) infrastructure is sustainable (GOI, 2014). Thus, the rapid urbanization and technological advancement urge to recreate and manage the existing cities for future development by integrated planning

(Maheshwari et.al, 2016). Smart Cities can cope up with the challenging issue related with urban population explosion.

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.1.1). 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. 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, and so on. Thus, program of urban development towards Smart Cities are at best targeted to achieve the second level of human needs.

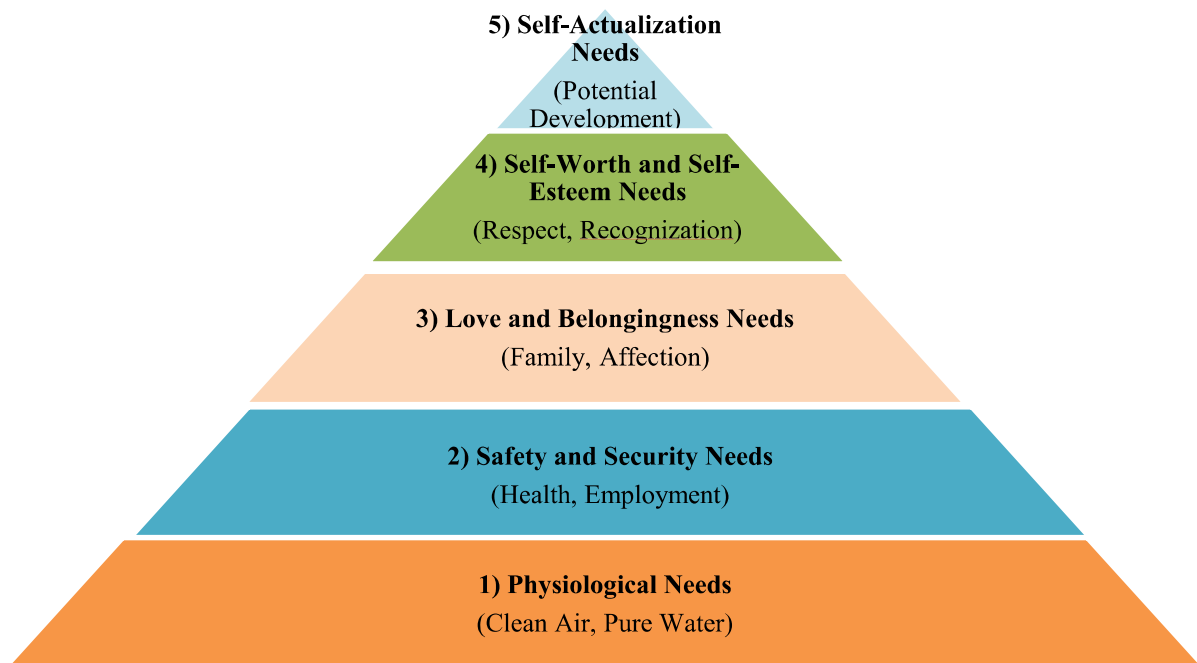


Fig. 1.1: Maslow’s hierarchy of needs (Maslow 1943)

1.2 Smart Cities Mission (SCM) in India

Smart Cities Mission (SCM) in India was initiated in June 2015. Guidelines have been proposed by the Ministry of Urban Development (MoUD, 2015) to highlight the requirements for the development of a smart city. SCM is a bold initiative by the government to reduce the urban service deficiencies and focuses on making the cities sustainable and inclusive. The launch of SCM has brought an optimistic approach among decision-makers and had attracted attention of financial investors. The core infrastructure development through SCM in the Indian scenario comprises 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).

Before the advent of SCM in India, many initiatives were taken as a part of city development programs. In the year 2005-06, Jawaharlal Nehru National Urban Renewal Mission (JNNRUM) was commenced for a period of seven years (2005-2012). The objective of this mission was to upgrade the urban infrastructure and governance (MoUD, 2006). Inappropriate urban planning, delay in project implementation, and leveraging of

funds were found as some of the difficulties in this initiative. JNNRUM was replaced by Atal Mission for Rejuvenation and Urban Transformation (AMRUT) in 2015 to focus on infrastructure creation. 500 cities were selected to provide better services in the field of water supply, sewerage, septage, storm water drainage etc. The universal coverage of selected indicators is to be ensured in five years of the mission, but in case of lack of funds, priority will be given to the water supply followed by the sewerage (MoUD, 2015). Heritage City Development and Augmentation Yojana (HRIDAY) was launched in 2017 to develop basic services in heritage cities. Its implementation will be program based rather than project based (MoHUA, 2017).

1.3 Decision Support System (DSS)

The application of information and communication technology (ICT) in the city development program is the core feature of Smart City initiatives. Decision Support System (DSS) is a specific class of computerized information system that supports business and organizational decision-making activities. A properly designed DSS is an interactive software-based system intended to help decision-makers compile useful information from raw data, documents, personal knowledge, and/or business models to identify and solve problems and make decisions. According to Scott- Morton (1971), DSS is “an interacting computer-based system that helps the decision-maker in the use of data and models in the solution of unstructured problems.” Arguably the use of DSS may also help in strategic planning, especially in the context of policy decisions for investment in city infrastructure development.

1.3.1 Environmental Decision Support System (EDSS)

Guariso and Werthner (1989) first coined the term Environmental Decision Support System (EDSS). It is used as a standard information system at international, national, and

state levels (Denzer, 2005). In the environmental domain, EDSS can reduce the time and improve the consistency and quality of the decisions taken to preserve the natural environment (Cortes et al., 2001, Haagsma and Johanns, 1994). An EDSS is interactive software that links knowledge-based techniques with mathematical models and algorithms that will help the environmental decision-makers to predict the future scenario and make suitable decisions between different alternative measures (Bruke, 2004). EDSS consists of integrated environmental models, database assessment, and management tools under Graphical User Interface (GUI), which can be realized by mapping and visualization of the results and scenario generation using spatial database management provided by geographical information systems (GIS) (Matthies, 2007). Fig. 1.2 depicts a schematic of an EDSS. At a glance, one can see that this kind of system offers a generic framework to integrate data, text, maps, objects, images, videos, environmental models, and knowledge with user-friendly tools, including database management systems, mapping systems, visualization, advanced statistics, analytical functions, and expert systems/artificial intelligence tools to produce outputs for interpretation, integration, post analysis and recommendation. Different researches and approaches in the field of EDSS have resulted in the diminishing of demarcating the boundary between the numerical/mathematical modelling and decision support system.

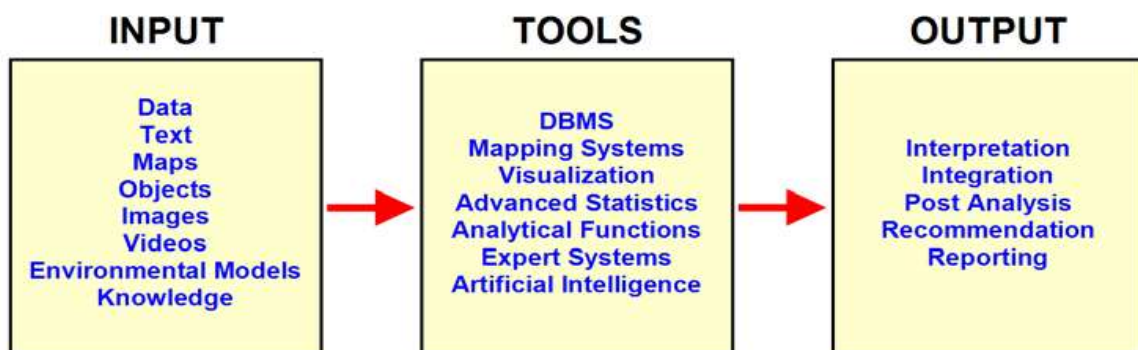


Fig. 1.2: Conceptual diagram of an Environmental Decision Support System (EDSS)

(Booty and Wong, 2010)

1.4 Transformation of Cities across the globe

The transformation of cities in developed and developing countries of the world may be depicted, as given in Fig.1.3. The concept of Sustainable development was first introduced in the Brundtland Commission Report of 1987 (WCED, 1987). The term ‘sustainability’ itself integrates the idea of developmental measures with environmental protection (Höjer and Wangel, 2015). Gradually, a paradigm shift was observed in which the cities started striving towards smart targets (Marsal- Llacuana et al., 2015); thus the concept of smart cities manifested in 1994 (Dameri and Cocchia, 2013). However, it was further realized that the smart targets and sustainability goals are interconnected. Thus, due to the amalgamation of sustainability goals, rapid urbanization, environmental issues, and blooming of ICT, the concept of ‘Smart Sustainable Cities’ emerged in the developed countries around 2010 (Hojer and Wangel, 2015).

In context to developing countries including India and Maldives, the policies and programs of city development implemented before 2015 generally lacked the sustainability quotient (Randhawa and Kumar, 2017). The SCM of Government of India is a new techno-urban development program which includes several elements of environmental infrastructures along with ‘sustainable environment’ as a defined objective. Thus, there seems an enhanced opportunity to develop models of Environmentally Sustainable Smart Cities (ESSC) applicable in this part of the world.

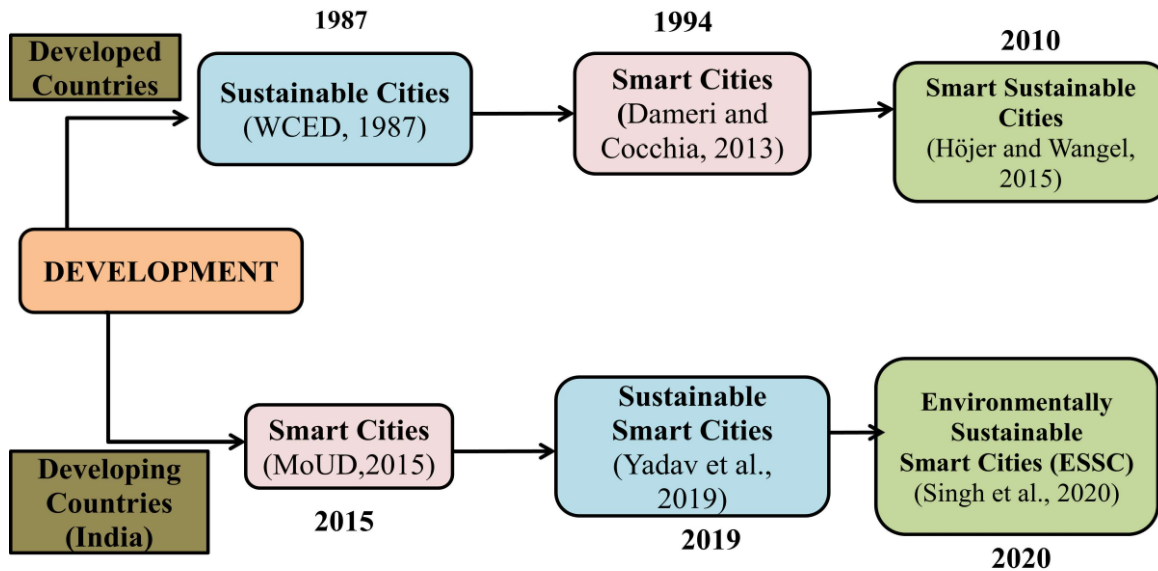


Fig. 1.3: Transformation of Cities in Developed and Developing Countries

1.5 Research Issues

Smart Cities Mission (SCM) was introduced in June 2015 by the Ministry of Urban Development (MoUD), Government of India (GOI), with an idea to develop 100 smart cities in the country (MoUD, 2015). It has been developed for setting in motion a virtuous cycle of growth and development for improving the quality of life and attracting ventures for the city. Thus, while in developed countries, after working on ‘sustainable cities’ over several decades, currently the cities are being planned as ‘Smart Sustainable Cities’, in India, the smart cities mission (SCM) is perhaps the first program of its kind to interject scientific tools and techniques including ICT in development and support of urban life management. Essentially, in long-term visions, developmental programs initiated under this mission must be directed to form ‘Sustainable Smart Cities (SSC) (Yadav et al., 2019). Accordingly, the plans and projects must be monitored using indicators of sustainability from the initial phases itself to ensure long-term benefits. However, as observed by Yadav et al., (2019), environmental protection finds very low priority amongst the ‘enablers’ of sustainability (in India), and within the three pillars of

sustainability (social, economic, and environmental), the first two appear to outweigh the third. Thus, there appears a definite need to emphasize on Environmentally Sustainable Smart Cities (ESSC) in India.

In addition, a number of questions arise from the existing literature which urges to develop smart city which is environmentally sustainable. The first major concern is that smart cities rely more on ICT and how it can help to achieve sustainability is still unanswered. Moreover, the framework available can only be used as a ranking instrument, and cannot evaluate the contribution of smart city to enhance sustainability. Thus, based on the research issues and questions identified in the area of building Smart Cities for developing countries, the overall aim of the present study is to design a user-friendly decision support system (DSS) which helps the city planners and policymakers in defining, measuring and monitoring actions for developing Environmentally Sustainable Smart Cities (ESSC) in India.

1.6 Objectives

The specific objectives planned for the study are:

- (i) To identify environmental domains and their suitable indicators for Environmentally Sustainable Smart Cities (ESSC).
- (ii) To develop a Smart City Environmental Sustainability Index (SCESI) as a tool to measure, monitor, and manoeuvre the infrastructural development initiatives based on existing and planned environmental conditions.
- (iii) To develop a Decision Support System for Environmentally Sustainable Smart Cities (DSS-ESSC) that can guide working governmental agencies and policymakers for prioritization of activities using indicators.

(iv) Validation of DSS-ESSC application and analysis of observations.

(v) Application of DSS-ESSC for planned Smart Cities and suggesting a time-bound improvement plan for achieving the targets of ESSC.

1.7 Organization of Thesis

The thesis has been structured based on the objectives of the study: development of an application-DSS-ESSC for Environmentally Sustainable Smart Cities. After the first chapter on Introduction, Chapter 2 presents the literature review related to the framework of Sustainable Cities and Smart Cities. This chapter also covers Decision Support System (DSS) application in the field of Smart Cities. At the end of the chapter, the research gap is also discussed.

Chapter 3 gives a detailed description of the methodology adopted for the development of a framework to calculate Smart City Environmental Sustainability Index (SCESI), the working principle of the Decision Support System.

Chapter 4 presents the validation and application part of the developed software.

Chapter 5 deals with the concluding remarks.