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"Challenges of Smart Cities: Methods of Prioritization"

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Abstract:

Smart city development has gotten considerable recognition in systematic literature and international policies throughout the world. The study aims to identify the key barriers to smart cities from the review of existing literature and the views of experts in this area. This work further made an attempt on the prioritization of barriers to recognize the most important barrier category and ranking of specific barriers within the categories to the development of smart cities in India. Through the existing literature, this work explored 31 barriers to smart cities development and divided them into six categories. This research work employed the fuzzy Analytic Hierarchy Process (AHP) technique to prioritize the selected barriers. Findings reveal that 'Governance' is documented as the most significant category of barriers to smart city development followed by 'Economic; 'Technology'; 'Social'; 'Environmental' and 'Legal and Ethical'. In this work, author also performed sensitivity analysis to show how robust is the findings of study. This research is useful to the government and policymakers for eradicating the potential interferences in smart city development initiatives in developing country like India.

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Keywords: Smart Cities, Barriers, Fuzzy AHP, India, Sensitivity Analysis, Prioritization.

1- Introduction

Smart city development has gotten considerable recognition in systematic literature and international policies in the last two decades (Albino et al., 2015; Koo et al., 2017; Mori and Christodoulou, 2012). For this work, a smart city can be defined as a technologically advanced and modernised territory with a certain intellectual ability that deals in with various social, technical, and economic aspects of growth based on the smart computing techniques to develop the superior infrastructure constituents and services (Bakici et al., 2012; Cruz-Jesus et al., 2017; Washburn et al., 2010; Zygiaris, 2013).

As per the United Nations Population Fund, a large proportion of population will shift to city regions by 2050 (UNFPA, 2008). In India, the urbanisation is growing rapidly, and cities are likely to expand to 600 million by 2030. Other study by Mckinsey (2018) reported that in the following 15 years, around 200 million people will shift from rural to urban areas in India. The change will be enormous, nearly equal to the existing populations of France, Germany, and the United Kingdom combined. In this sense, the Government of India (GoI) is committed to enhance the quality of life of citizens through its urban development agenda (Bloomberg Philanthropies, 2017; Nair, 2017). In this support, GoI has listed 109 of India's most popular urban centres where the focus shifts from "highways to i-ways". The urban population of India is growing with a lesser rate as compared to global average (31.15% as per the 2011 census of India). The reason for this may be lack of governmental supportive polices or challenges in managing the urban dynamics. On the other hand, the countries such Chile, Mexico, Argentina, Brazil and China have responded timely by launching various initiatives to manage the urbanization efficiently (Aijaz, 2016). For example, Santiago de Chile has shown advancement on the drive of being smarter (Fast Company, 2013). Similarly, Chinese city Xinxiang pursued a joint programme with IBM to improve its transportation network and community safety (China Daily, 2012). In citizens' quality of life index, the countries such as Denmark, Switzerland and Australia are performing well above compared to Asian countries including India. For improving the quality of life, policymakers conducted an initiative of smart city development in India (OECD, 2015; The Indian Express, 2016). However, cities in developing country like India are extremely different to design and put into practice.

Cities generate new kinds of problems such as scarcity of resources, air pollution, difficulty in waste management, traffic congestions, and inadequate, deteriorating and aging infrastructures etc. (Chourabi et al., 2012). In recent years, a sequence of challenges in the cities' economies and needs have arisen, administering the promotion of the smart city idea

In addition, literature also lacks a clear understanding and strategic planning of smart city projects (Angelidou, 2015). There is a clear literature gap exists in smart city agenda on its theoretical development and evaluation of related challenges that facilitate its implementation in a country context (Yigitcanlar, 2015). Therefore, key barriers to the smart cities' development need to be identified and evaluated.

To help policymakers, in this work, the key barriers to the smart cities' development are identified from literature evaluation and experts' feedback. Different experts might have different opinions regarding the barriers to the smart cities' development in India. So, the experts on smart cities with regard to academia, industry and public-sector organisations were made part to provide their views on the various barriers that might come to a way to the smart cities development. Specifically, this research sets the following objectives:

[i] Identification of relevant barriers of smart cities development in India

[ii] Prioritisation of barriers to recognise the most important barriers of smart cities development in India

The selection of barriers was made through literature and inputs received from experts. Prioritizing the barriers is a decision problem involving various criteria and sub-criteria. Various difficulties supplement the prioritization of barriers due to human involvement and indistinctness in data (Mangla et al., 2017). To remove the essential imprecision and ambiguity, this work use the fuzzy set theory (Zadeh, 1965). In this work, author prefer to go for the fuzzy AHP (Analytic Hierarchy Approach) because this technique is significant in knowing the importance of the identified barriers under fuzzy surroundings (Govindan et al., 2015). The fuzzy AHP permits mixing fuzzy set theory with the AHP technique to capture the human bias in judgements when developing pair-wise comparisons between barriers.

The remaining sections of the paper are structured as follows: Section 2 presents the related literature on smart cities and highlights the barriers of smart cities development. Section 3 discusses the solution methodology along with the research framework. Section 4 illustrates the data analysis and results. Section 5 presents the sensitivity analysis to examine the priority rank stability. Section 6 discusses the results for this work. Section 7 presents the managerial implications and contributions to the theory. Finally, Section 8 provides conclusions, limitations and directions of future research.

2- Literature Review

This section illustrates the literature linked to smart cities, and identifies the barriers related to smart cities development.

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2-1 Smart Cities Development

The concept of smart city was first addressed in 1990s with an aim to centre the implications of information communication technology for superior infrastructures and upgradations in network. The widespread use of information technologies also helps cities to empower the advancement of indispensable services for safety, health, governance and delivery (Hernandez-Munoz et al., 2011; Pereira et al., 2017). For assisting policymakers on smart city network design, the California Institute for Smart Communities explored the way of transforming a city into smart city along with the extent of utilisation of information technologies in smart city context (Alawadhi et al., 2012; Albino et al., 2015). As a very significant and highly sensible initiative, the European Commission has started plans on smart cities in 2010 that underpins four dimensions for the cities including constructions, heating and cooling systems, power and transportation. The objective related to transportation, for example, is to build intelligent public conveyance and traffic management system that avoids congestion, helps reduced fuel consumption and safety measures (Djahel et al., 2013).

A latest GSMA report also recommends that transportation, such as intelligent transportation and traffic information systems play important role in smart cities projects (Lee et al., 2014). The European Commission has also endorsed "the smart city" calls to improve energy efficiency and green mobility for the community (Lazaroiu and Roscia, 2012). Lee et al. (2013) suggested six key dimensions for the concept of smart city, in terms of economy, mobility, environment, people, living and governance. As of 2012, there were about 143 smart cities projects out of which 35 projects in North America and 47 projects in Europe were seeking to adopt smart technologies in managing urban issues. Some of them are – traffic congestions, energy requirements, higher resources etc. (Lee and Lee, 2014). According to pan-

European research project Intel Cities (2009), effective governance is key to smart city development (Paskaleva, 2011). A review of diverse definitions and practices of smart cities across the world also indicates that most of the smart cities make a widespread use of mobile infrastructure and services (Lee et al., 2014). In respect of increasing urban population and improved service quality in India, researches and policymakers should have a high understanding on smart city and its relevant barriers.

2-2 Barriers of smart cities development

Based on previous studies, this work listed 31 key barriers to smart city development. These barriers were also confirmed further through experts. This work categorised these barriers into six key categories with experts' consultation; other details for data collection is provided in Section 4. The various categories and associated barriers are presented in Table 1.

Table (1): The Various Categories and Associated Key Barriers to Smart Cities Development

Category	S. No.	Key Barriers	Description	Reference
Governance (GOV)	1	Lack of cooperation and coordination between city's operational networks (GOV1)	Lack of ties between operational nodes in the smart cities implementation	Elmangoush et al. (2013); Kogan (2014); Tachizawa et al. (2015)
	2	Unclear IT management vision (GOV2)	The lack of vision on how IT management can be effectively imposed to the development of the smart cities	Chourabi et al. (2012)
	3	Political instability (GOV3)	Smart cities will not become a reality until there is a political stability	Kogan (2014); Letaifa (2015)
	4	Lack of trust between governed and government (GOV4)	Lack of trust between government and people can impede smart cities development	Balta-Ozkan et al. (2013); Monzon (2015)
	5	Poor private-public participation (GOV5)	The poor private-public interaction can negative impact smart cities development projects	Koppenjan and Enserink (2009); Lee et al. (2014)

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	6	Lack of developing a common information system model (GOV6)	Lack of a common IS model to ensure end-to-end visibility while managing smart city infrastructure and services.	Ballon et al. (2011); Naphade et al. (2011)
Economic (ECO)	7	High IT infrastructure and intelligence deficit (ECO1)	Lack of IT infrastructure (e.g. solar based electrical systems, cloud computing) and capabilities of artificial intelligence (e.g. intelligent transport system, smart communities, e-health, smart grids, smart energy solutions etc.)	Monzon (2015)
	8	Lack of competitiveness (ECO2)	Lack of competitiveness among local firms to deal with the challenges emerged in the development of the smart cities.	Monzon (2015)
	9	Cost of IT training and skills development (ECO3)	High cost of IT training and skills development programme to the IT professionals is a barrier to the smart cities development	Chourabi et al. (2012)
	10	Global economy volatility (ECO4)	Increasing volatility and uncertainty in the global economy could be a major concern for the smart cities development	Ferrara (2015)
	11	Higher operational and maintenance cost (ECO5)	High cost of IT, professionals and consultancies, installation, operation and maintenance and training are concerns for the smart cities development	Chourabi et al. (2012)
Social (SOC)	12	Lack of involvement of citizens (SOC1)	Lack of citizens’ participation in realising how exactly the smart cities could possibly look like in their experience is reflected. The citizens should be encouraged to submit and evaluate ideas for innovation in smart city design.	Komninos et al. (2013); Kogan (2014); IET (2017); Schuurman et al. (2012)
	13	Low awareness level of community (SOC2)	Public lacks in understanding the idea of smart city, and its implications on their quality of life	IET (2017); Kogan (2014)
	14	Geographical diversification problems (SOC3)	Unbalanced geographical development can hamper the smart cities development	Monzon (2015)
	15	Degree of inequality (SOC4)	High degree of inequality in citizens’ education, income, skills etc. can impede the smart cities development	Glaeser et al. (2009); Monzon (2015)
Technology (TECH)	16	Lacking technological knowledge among the planners (TECH1)	The planners and policymakers of smart cities development lack enabling or transformative technological knowledge that may be needed for smart cities development	Scuotto et al. (2016)
	17	Lack of access to technology (TECH2)	Lack of access to modern digital technology to majority of citizens can be a barrier toward smart cities development	Chourabi et al. (2012); Monzon (2015)

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	18	Privacy and security issues (TECH3)	Issues related to privacy and security (e.g. threats from hackers and viruses, low privacy, high costs etc.) tend to be a major concern for smart cities development	Balta-Ozkan et al. (2013); Chourabi et al. (2012); Elmaghraby and Losavio (2014)
	19	System failures issues (TECH4)	This failure could be anything from city-wide public Wi-Fi systems to the provisions of smart water meter in individual homes	Datta (2016)
	20	Integration and convergence issues across IT networks (TECH5)	Lack of integration of disparate technology and convergence of heterogeneous networks (e.g. Bluetooth, WLAN, heterogeneous cellular networks such as 3G, 4G, 5G etc.) could be potential issues toward smart cities development	Chourabi et al. (2012); Kogan (2014); Lee et al. (2014)
	21	Poor data availability and scalability (TECH6)	There is a lack of specific data and corresponding scalable methods in smart city development agenda	Gluhak (2017)
Environmental (ENV)	22	Lacking ecological view in behaviour (ENV1)	Lack of ecological view in pro-environmental behaviour toward consuming energy	Kogan (2014)
	23	Growing population problems (ENV2)	Rapidly increasing population could be a concern for the smart cities development	Neirotti et al. (2014)
	24	Lack of sustainability considerations (ENV3)	Lack of more sustainable and more aware city (e.g. direct traffic, notify residents about available parking, reduce gas emissions etc.) means lack of better living conditions and experiences for all	Neirotti et al. (2014); Yoon (2015)
	25	Carbon emissions effect (ENV4)	Inability of shifting cities toward low carbon trajectory and emission reduction actions	Mandal (2016)
	26	Degradation of resources (ENV5)	Shortage of resources like supply of fresh water and food	Monzon (2015)
Legal and Ethical (L&E)	27	Cultural issues (L&E1)	Lack of inflow of creative and sharing culture of the people living together in smart cities	Nam and Pardo (2011); Chourabi et al. (2012); Monzon (2015)
	28	Lacking standardization (L&E2)	Lack of standardization across indicators (e.g. smart technologies, security, privacy, quality of life, environmental sustainability, physical infrastructure, mobile networks etc.) has emerged as one of the crucial hindrance in smart city context	Bhattacharya et al. (2015); Kogan (2014)
	29	Issues of openness of data (L&E3)	Open data and its accessibility is an issue in the smart cities, which can impede the way the smart city services can be delivered to cities' residents and businesses	Kogan (2014)

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	30	Lack of transparency and liability (L&E4)	Inhibited transparency and unclear lines of political accountability in delivering most services could be a concern for smart cities development. The lack of transparency risks isolating the very people smart cities technology is supposed to serve	Nam and Pardo (2011)
	31	Lack of regulatory norms, policies and directions (L&E5)	Lack of appropriate laws, regulations or directives for the smart cities development	Chourabi et al. (2012)

3- Solution Methodology

This is exploratory research, to develop a theoretical background in a smart city context. We used the fuzzy AHP as the research method. Fuzzy AHP allows knowing the importance weights of the smart cities related barriers and their categories of barriers. Thomas L. Saaty introduced AHP in 1980. It is a decision-making tool, which assists in developing a hierarchy structure of variables (Luthra et al., 2013; Luthra et al., 2016). AHP/Fuzzy AHP is superior to other decision analysis methods like fuzzy TOPSIS/TOPSIS, fuzzy ANP/ANP, and ELECTRE and due to their limited acceptability and complexity (Harputlugil et al., 2011; Mangla et al., 2017). AHP is very simple to use and reveals superior results for managers. AHP helps to find out the alternative, which best accords to achieve the defined goal and understanding of the problem. However, human presence always contains subjectivity, which limits the application of AHP (Mangla et al., 2015). AHP provides the numerical priorities for each variable to attain the goal (Ordoobadi, 2010). However, AHP has its own limitations, described as (Ishizaka and Labib, 2009; Mangla et al., 2016):

i. Problem of rank reversal or changes in priority due to any changes in factors or alternatives
ii. The hypothesis of factors independence.

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iii. Human bias and subjectivity in their judgments in forming pair-wise comparisons
iv. Consensus measure

To deal with above problems, AHP techniques can be extended to modified AHP – Bayesian approach, Fuzzy AHP, and Grey AHP (Govindan et al., 2017; Kar, 2015; Sahoo et al., 2016). Among all these, fuzzy AHP is highly preferred, due to its simplicity and higher consistency (Junior et al., 2014; Prakash and Barua, 2015). Fuzzy AHP technique also allows (i) analysing the behaviour of complex system in decision-making; (ii) evaluating the human judgment by determining the relative importance of system variables. Therefore, this research proposes to use a fuzzy based AHP approach for prioritizing the barriers in smart city development in India. The flow map for the fuzzy based AHP technique is shown in Fig. 1, and the steps involved are explained as follows:

The fuzzy AHP involved several steps (Chan et al., 2008) as follows: Step 1: Formulating and defining the aim of research work: The aim of work to prioritize the barriers in smart cities development is defined. Step 2: Applying the fuzzy concepts: In a decision-making problem generally involves human assessments consist of qualitative judgments. Thereby, the fuzzy concepts are preferred (Dubois and Prade, 1979; Zadeh, 1965). The triangular fuzzy number (TFN) is used in this work. Step 3: Constructing a hierarchical structure: In respect to the aim of this work, a hierarchical structural keeping the experts' view into account is formed. Step 4: Developing a fuzzy pair wise assessment matrix: The pair wise assessment matrix for the barriers are formed. Prior to this, a nine-point scale of relative importance based on TFNs is designed (Table 2). Experts generally provide their feedback in

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terms of linguistic statements thus fuzzy scores were used to transform their linguistic inputs into numbers.

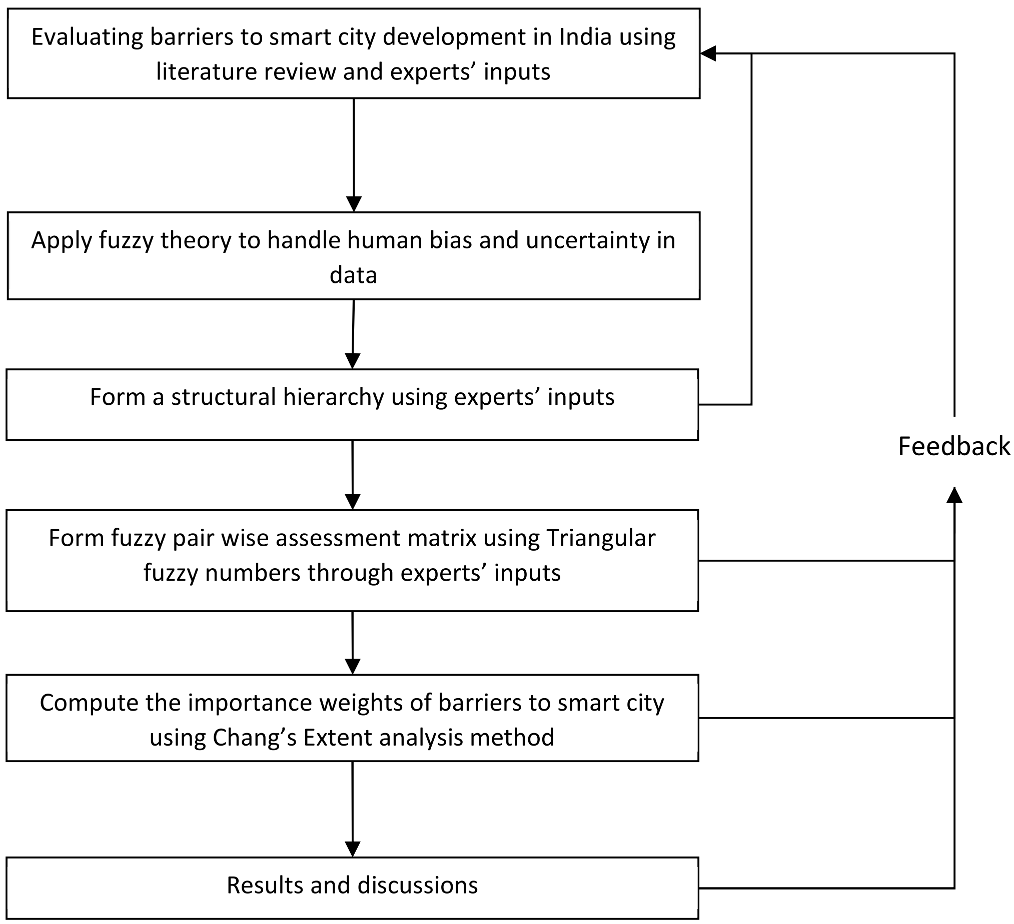

Fig. (1): Fuzzy AHP Flow Diagram for This Work

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Table (2): Fuzzy Linguistic Scale (Source: Mangla et al., 2015)

Uncertain judgment	Fuzzy score
Almost equivalent	1/2,1,2
Almost x times more important	x-1, x, x+1
Almost x times less important	1/x+1, 1/x, 1/x-1
Between y and z times more important	y, (y + z)/2, z
Between y and z times less important	1/z, 2/(y + z), 1/y

Note: The values of x range from 2, 3...9, whereas the values of y and z can be 1, 2...9 with y<z

In order to develop a positive fuzzy comparison matrix (M), the average of the pair wise comparisons from expert panel is computed, which is given as $M = [m_{uv}]_{n \times m}$. Where, m_{xy} shows the fuzzy entries in the developed fuzzy positive matrix, i.e., (i_{uv}, j_{uv}, k_{uv}). Further, positive fuzzy numbers should also satisfy the properties, given as below:

$i_{uv} = \frac{1}{i_{uv}}, j_{uv} = \frac{1}{j_{uv}}, \ k_{uv} = \frac{1}{k_{uv}}$, where, u and v = 1, 2 ………………z, i.e., no. of criteria.

Step 5: Devising barriers significance weights: The fuzzy assessment matrix is further evaluated using Chang's Extent Analysis method (Chang, 1996; Luthra et al., 2015; Mangla et al., 2017). This helps in determining the significance weights of barriers.

A conceptual framework for analysing the identified inhibitors relevant to smart city development is proposed (see Fig. 2). The framework is developed by following the guidelines of Platts and Gregory (1990) and given below:

i. Involved processes are strictly relevant to the existing framework. Analysis of the literature, selection of barriers and research methodology applicability all are associated with the research aim.
ii. Involved processes of the framework are well supported by literature and thereafter verified through experts' feedback. The conceptual research framework

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consists of two phases. In Phase 1, this work seeks to select the most suitable barriers to smart city development in Indian context. The selection of the most suitable barriers is grounded on literature survey and feedback received from the experts'. In Phase 2, we seek to explore the relative importance of the listed most suitable barriers and the categories of barriers. To achieve this, fuzzy based AHP approach is used (see Section 5.3). However, the suggested framework is not tested empirically at this stage of this work.

The conceptual framework depicts a real-life illustration of the issues of smart city development in India perspective as presented in Section 4. However, questionnaire and data collection is demonstrated in the next sub-section.

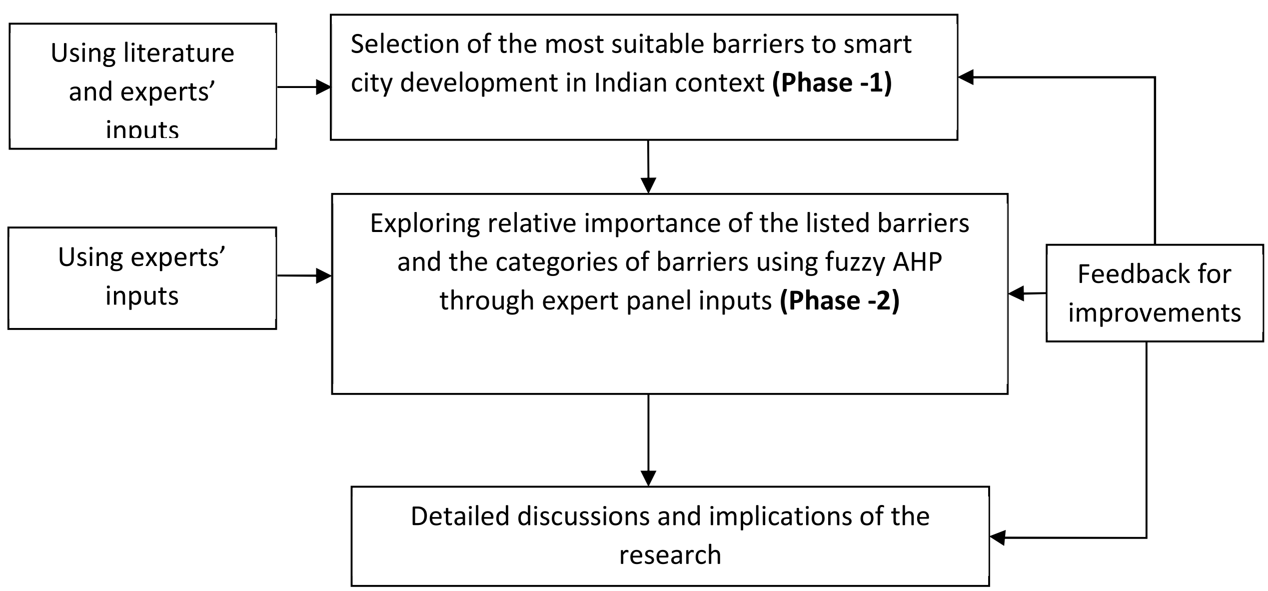

Fig. (2): Proposed Framework

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4- Questionnaire development and data collection

A total of 31 barriers under six categories to smart cities development were identified from the extensive literature review. This work has been conducted in an Indian case context (single case study type). The case study approach is significant in theoretical development to the domain (smart city agenda). The case study research can also reveal the cognitive behaviour of the system, and thus underpins the empirical research in domain (Voss et al., 2002). Due to the insufficiency in theory and expertise on smart city, this work prefers to discourse on smart city development using expert's opinions (Mangla et al., 2015). Initially, twenty experts linked to smart cities project were contacted by phone, emails and direct visit to explain the need and importance of smart cities in the country. The selection of the experts was made on the basis of researchers' convenience, cardinal consensus and personal contacts. Only eight out of twenty experts were interested to participate in this research. This is considered as a satisfactory size for the present case based research (Lin, 2013; Luthra et al., 2015) provided that experts selected represent an intensive understanding of smart city development projects in Indian context. To examine the barriers to smart cities development in Indian context, we conducted a one-day workshop on "Smart City Design" on March 7, 2017 at New Delhi, India. The experts were highly skilled professionals from finance and operations, project management skills, ministry level professionals, environment management, and decision analysts.

Overall, this work can be applied to some limited context conducted with a comparable sample size (8 experts) but confirm basis for further research that may be generalised to bigger populations. For more clarity on expert's background, the demographic summary of experts with various criteria is provided in the Table 3.

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Table (3): Experts' Demographic Information

Category	Classification	No. of experts
Educational Qualification	Bachelor	0
	Master	3
	Ph.D.	5
	Others	0
Work Experience	Less than 5 Years	0
	5 to 10 Years	1
	11 to 15 Years	2
	16 to 20 Years	4
	Greater than 20 Years	1
Size of Organization	Less than 50 Employees	0
	51 to 250 Employees	2
	251 - 500 Employees	1
	501 – 1000 employees	2
	1001 – 5000 employees	1
	Greater than 5001 employees	2
Sector Classification	Private Sector	2
	Public Sector	5
	Multinational Corporation	0
	Regulatory Bodies	0
	Mixed public and private ownership	1
	Additional sector type	0

5- Data Analysis and Results

Fuzzy AHP is utilized to find the dominant barriers to smart city development in Indian context. Data analysis and related results have been provided. The proposed framework is applied to the research problem under study with other details as below:

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Phase 1: Most Suitable Barriers Relevant to Smart City Development

The author explored the literature using specific keywords including barriers and smart cities development; challenges and smart cities development; problems/issues and smart cities development in their various forms in Scopus database and Google Scholar. Author also searched some grey literature, web content, government consultation documents, policy papers, to search for the barriers of smart cities development. A comprehensive review of keywords across various literature surveys fetched us 31 key barriers to smart cities development.

To validate these literature based barriers, a brainstorming session was conducted with the consent of experts. The experts were asked to rate the listed barriers in smart city adoption on 5-point Likert scale (1= not at all and 5=very significant) through the questionnaire. The mean scores of barriers and their standard deviations to smart cities development in the Indian context are also identified as given in Table 4.

The barriers with rating of 2 or mean value less than 2 were decided to be deleted. From Table 4, no barrier has obtained mean value less than 2, so as no barrier was deleted from the list. The experts were also asked to make any modification in the list of barriers; however, all the experts were agreed on the 31 literature-based barriers. In this way, all the identified 31 barriers were validated.

Table (4): Mean Score of Barriers to Smart City Development

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S. No.	Barriers to Smart Cities Development	Mean	SD
1	Lack of cooperation and coordination between city's operational networks (GOV1)	3.25	0.71
2	Unclear IT management vision (GOV2)	3.88	0.83
3	Political instability (GOV3)	3.38	1.06
4	Lack of trust between governed and government (GOV4)	3.50	1.20
5	Poor private-public participation (GOV5)	3.75	1.39
6	Lack of developing a common information system model (GOV6)	3.13	1.13
7	High IT infrastructure and intelligence deficit (ECO1)	3.38	1.30
8	Lack of competitiveness (ECO2)	2.25	1.28
9	Cost of IT training and skills development (ECO3)	2.63	1.06
10	Global economy volatility (ECO4)	2.25	1.28
11	Higher operational and maintenance cost (ECO5)	3.50	1.69
12	Lack of involvement of citizens (SOC1)	3.50	1.20
13	Low awareness level of community (SOC2)	3.88	1.36
14	Geographical diversification problems (SOC3)	2.88	1.13
15	Degree of inequality (SOC4)	3.38	0.92
16	Lacking technological knowledge among the planners (TECH1)	3.75	0.71
17	Lack of access to technology (TECH2)	3.25	1.04
18	Privacy and security issues (TECH3)	3.25	1.04
19	System failures issues (TECH4)	3.50	0.76
20	Integration and convergence issues across IT networks (TECH5)	3.63	0.92
21	Poor data availability and scalability (TECH6)	3.50	1.20
22	Lacking ecological view in behaviour (ENV1)	2.63	0.92
23	Growing population problems (ENV2)	3.00	1.07
24	Lack of sustainability considerations (ENV3)	2.88	0.64
25	Carbon emissions effect (ENV4)	2.63	0.92
26	Degradation of resources (ENV5)	2.75	1.49
27	Cultural issues (L&E1)	2.63	1.19
28	Lacking standardization (L&E2)	3.13	0.99
29	Issues of openness of data (L&E3)	3.00	0.93
30	Lack of transparency and liability (L&E4)	3.50	1.07
31	Lack of regulatory norms, policies and directions (L&E5)	3.75	1.39

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In this phase, the previously identified thirty-one barriers were presented to experts for developing some appropriate categories of barriers. The experts have suggested the idea of evaluating 31 barriers in case of smart city development in a developing economy like India through PESTEL analysis. However, government has a vital role in initiating and executing smart city projects in India. One of the experts suggested the inclusion of Ethics along with Legal aspects for PESTEL analysis. This is the reason additional categories of Governance and Ethics is added to PESTEL analysis. In this sense, 31 most relevant barriers within 6 categories with PESTEL analysis were examined further to know their priority using expert panel inputs.

Phase 2: Prioritizing The Smart City Development Barriers by Means of Fuzzy AHP

In this stage, the finalized smart city development barriers and their categories were evaluated to know their significance. Due to human involvement, this process of prioritizing the barriers may be biased, and thus, fuzzy AHP technique is used.

- **Hierarchical structure**

A hierarchical structure for this research is developed using expert inputs. The developed decision hierarchy contains of three distinct levels, given as, prioritizing the barriers to smart city development (at Level-1), six categories of barriers (at Level-2) and thirty-one smart city redevelopment related barriers (at Level-3) (see Fig. 3).

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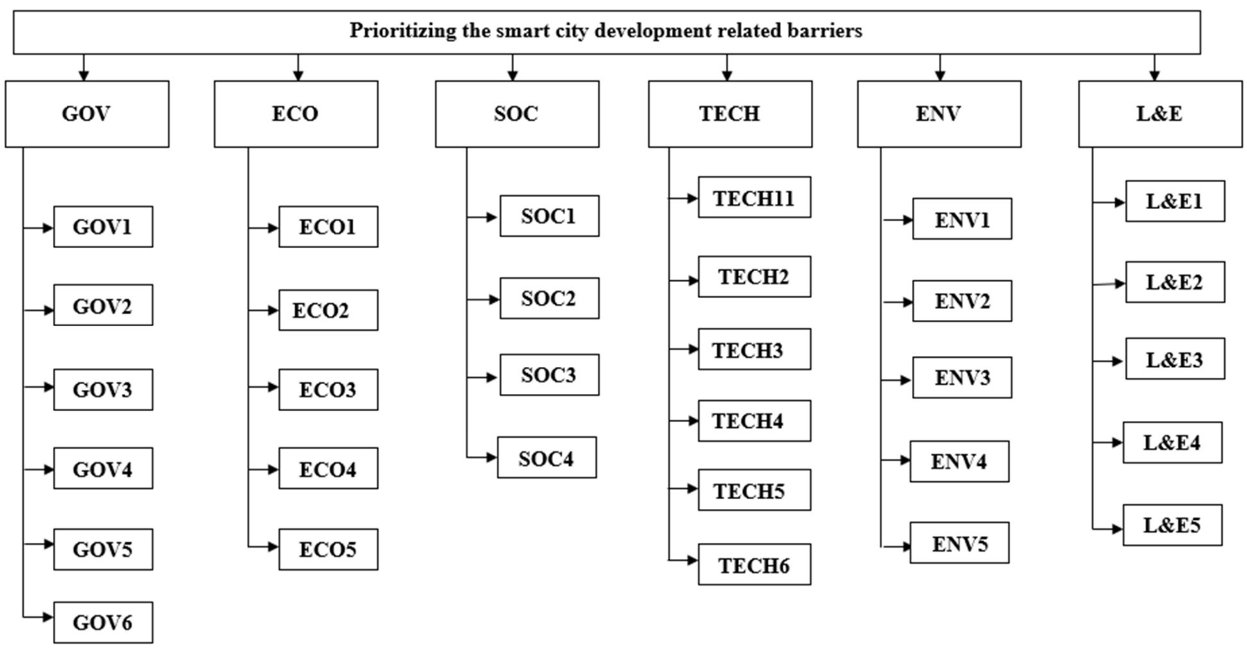

Fig. 3 The developed decision hierarchy of barriers to smart city development

- **Formation of the fuzzy pair wise assessment matrix**

Pair wise assessments are formed for barriers by using experts' inputs by means of a scale (see Table 2). The professional in expert panel evaluated the pair wise rating by using linguistic statements and expressions. Expert opinion (majority of expert's opinion) (Mangla et al. 2015) helped to finalize the pairwise comparison matrix of barriers. We also conducted a group session to locate any major deviation in the pairwise comparisons and develop agreement among expert's opinions. This iterative process helped to build the rigor in the selection process framework. In addition, use of fuzzy set theory and TFNs helps in managing the consistency for matrices (pairwise comparisons). Fuzzy set theory allows experts to provide their inputs using an interval as being illustrated in Table 4 above. In this sense, pairwise

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comparison of attributes is shown in Table 5. In this way, fuzzy pair wise assessment matrix for categories of barriers is finalized (see Table 5).

Table 5 Pair-wise judgment matrix for categories of barriers to smart city development

Categories of barriers	GOV			ECO			SOC			TECH			ENV			L&E		
GOV	1.00	1.00	1.00	2.00	3.00	4.00	0.25	0.29	0.33	0.33	0.40	0.50	2.00	3.00	4.00	3.00	4.00	5.00
ECO	0.25	0.33	0.50	1.00	1.00	1.00	1.00	2.00	3.00	3.00	3.50	4.00	0.33	0.40	0.50	2.00	3.00	4.00
SOC	3.03	3.45	4.00	0.33	0.50	1.00	1.00	1.00	1.00	0.33	0.50	1.00	0.33	0.50	1.00	1.00	2.00	3.00
TECH	2.00	2.50	3.03	0.25	0.29	0.33	1.00	2.00	3.03	1.00	1.00	1.00	0.50	1.00	2.00	0.50	1.00	2.00
ENV	0.25	0.33	0.50	2.00	2.50	3.03	1.00	2.00	3.03	0.50	1.00	2.00	1.00	1.00	1.00	0.33	0.50	1.00
L&E	0.20	0.25	0.33	0.25	0.33	0.50	0.33	0.50	1.00	0.50	1.00	2.00	1.00	2.00	3.03	1.00	1.00	1.00

- **Barrier preference weights and their relative importance**

The preference weights were devised in corresponds to each category and their specific barriers using Chang's Extent Analysis method. The associated S_i values can be computed, as follows:

$$S_1 = (8.58, 11.69, 14.83)\times\left(\frac{1}{68.6482,},\frac{1}{50.0740},\frac{1}{35.7970}\right) = (0.1250, 0.2335, 0.4143)$$

$$S_2 = (7.580, 10.2333, 13.00)\times\left(\frac{1}{68.6482,},\frac{1}{50.0740},\frac{1}{35.7970}\right) = (0.1104, 0.2044, 0.3632)$$

$$S_3 = (6.0236, 7.9483, 11.00)\times\left(\frac{1}{68.6482,},\frac{1}{50.0740},\frac{1}{35.7970}\right) = (0.0877, 0.1587, 0.3073)$$

$$S_4 = (5.25, 7.7857, 11.3939)\times\left(\frac{1}{68.6482,},\frac{1}{50.0740},\frac{1}{35.7970}\right) = (0.0765, 0.1555, 0.3183)$$

$$S_5 = (5.08, 7.3333, 10.5606)\times\left(\frac{1}{68.6482,},\frac{1}{50.0740},\frac{1}{35.7970}\right) = (0.0740, 0.1464\ 0.2950)$$

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$S_6 = (3.2833, 4.0833, 6.8636) \times \left(\frac{1}{68.6482}, \frac{1}{50.0740}, \frac{1}{35.7970}\right) = (0.0478, 0.0815, 0.1917)$

The degree of possibility for two fuzzy numbers is given as,

$V(S_1 \geq S_2) = \frac{(0.1104- \ .4143)}{(0.2335- \ .4143)-(0.2044 \quad .1104)} = 1.0000$

$V(S_1 \geq S_3) = 1$

$V(S_1 \geq S_4) = 1$

$V(S_1 \geq S_5) = 1$

$V(S_1 \geq S_6) = 1$

Next, the minimum weight vectors for each fuzzy number are calculated:

$z'(C_1) = \min V(S_1 \geq S_{2,} S_{3,}, S_{4,} S_{5,} S_6) = \min(1, 1, 1, 1, 1) = 1$

$z'(C_2) = 0.8890$

$z'(C_3) = 0.7310$

$z'(C_4) = 0.7410$

$z'(C_5) = 0.6920$

$z'(C_6) = 0.3040$

Next, the normalized values and their corresponding significance weights are computed. Thus, the weight vectors for the categories of barriers have been established and hence their relative importance are established (see Table 6).

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Table (6): Rank of Categories of Barriers to Smart City Development

Categories of barriers	Preference weights	Ranking
GOV	0.2295	1
ECO	0.2040	2
SOC	0.1678	4
TECH	0.1701	3
ENV	0.1588	5
L&E	0.0698	6

‘Governance (0.2295)’ is recognised as the most important category of barriers for smart city development followed by ‘Economic (0.2040)’; ‘Technology (0.1701)’; ‘Social (0.1678)’; ‘Environmental (0.1588)’ and ‘Legal and Ethical (0.0698)’ are shown in Table 5. In the next level, relative and global preference weights of specific barriers are determined (see Table 7). Based on this, the final ranks of barriers for smart city development have been made. Global ranking of barriers is summarized in Table 7.

6- Sensitivity Analysis

Generally, there is an immense imprecision and vagueness present in the data collection process. Sensitivity analysis monitors the priority ranking of the recognized barriers to smart cities development. Further, it has a tendency that can determine the smallest change in the ranking with the changes in relative weights of the barrier. In this sense, it is sensible to verify the priority ranks by altering the weights of all the categories of barriers (Mangla et al., 2015).

Table (7): Final Rank of Specific Barriers to Smart City Development

Category of barriers	Specific barriers	Relative preference weights	Relative ranking	Global preference weights	Global ranking
GOV	GOV1	0.1832	2	0.0420	6
	GOV2	0.1635	3	0.0375	8
	GOV3	0.2151	1	0.0494	4
	GOV4	0.1549	5	0.0355	12
	GOV5	0.1593	4	0.0366	9
	GOV6	0.1241	6	0.0285	20
ECO	ECO1	0.1762	3	0.0359	11
	ECO2	0.2602	1	0.0531	2
	ECO3	0.1540	5	0.0314	18
	ECO4	0.2449	2	0.0500	3
	ECO5	0.1647	4	0.0336	16
SOC	SOC1	0.3297	1	0.0553	1
	SOC2	0.2842	2	0.0477	5
	SOC3	0.2021	3	0.0339	15
	SOC4	0.1840	4	0.0309	19
TECH	TECH1	0.2286	1	0.0389	7
	TECH2	0.1870	2	0.0318	17
	TECH3	0.1554	3	0.0264	22
	TECH4	0.1486	4	0.0253	24
	TECH5	0.1454	5	0.0247	25
	*+- TECH6	0.1351	6	0.0230	26
ENV	ENV1	0.2157	3	0.0343	14
	ENV2	0.2270	1	0.0360	10
	ENV3	0.1639	5	0.0260	23
	ENV4	0.2207	2	0.0350	13
	ENV5	0.1728	4	0.0274	21
L&E	L&E1	0.2128	4	0.0149	30
	L&E2	0.2374	1	0.0166	27
	L&E3	0.2215	2	0.0155	28
	L&E4	0.2144	3	0.0150	29
	L&E5	0.1139	5	0.0080	31

In this research, 'Governance (GOV)' category is the topmost ranked among all (see Table 6). This category would affect the other categories of barriers for smart city development. For that reason, we varied the 'Governance' category relative weights from values 0.1 to 0.9 and changes in the weights of other categories were noted correspondingly (see Table 8).

Table (8): Values of Category of Barriers When Increasing Governance Category of Barriers

Listed categories	Values of preference weights for selected categories ↓									
GOV	0.2295	0.1001	0.2001	0.3002	0.4001	0.5002	0.6007	0.7001	0.8002	0.9001
ECO	0.2040	0.2383	0.2118	0.1853	0.1588	0.1323	0.1057	0.0794	0.0529	0.0265
SOC	0.1678	0.1960	0.1742	0.1524	0.1307	0.1089	0.0870	0.0653	0.0435	0.0218
TECH	0.1701	0.1987	0.1766	0.1545	0.1324	0.1103	0.0882	0.0662	0.0441	0.0221
ENV	0.1588	0.1855	0.1649	0.1442	0.1236	0.1030	0.0823	0.0618	0.0412	0.0206
L&E	0.0698	0.0815	0.0725	0.0634	0.0543	0.0453	0.0362	0.0272	0.0181	0.0091
Total	1	1	1	1	1	1	1	1	1	1

At 0.1 value of 'Governance' category, barrier SOC1 obtains the highest rank and barrier L&E5 obtains the lowest rank. Barrier SOC1 retains the highest rank and barrier L&E5 the lowest rank value until the normal value (0.2295) for Governance category is reached. From varying the Governance category weights value (from 0.3 to 0.9), barrier GOV3 holds highest rank, and the ranking of other barriers also vary accordingly. The changes in the weights of specific barriers when Governance category weights change from 0.1 to 0.9 have been presented in Table 9.

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Table (9): Relative Weights of Barriers by Sensitivity Analysis When 'Governance' Category Weights Change From 0.1 To 0.9

	GOV= 0.1	GOV= 0.2	GOV= 0.2295 (Normal)	GOV= 0.3	GOV= 0.4	GOV= 0.5	GOV= 0.6	GOV= 0.7	GOV= 0.8	GOV= 0.9
GOV1	0.0183	0.0367	0.0420	0.0550	0.0733	0.0916	0.1099	0.1282	0.1466	0.1649
GOV2	0.0164	0.0327	0.0375	0.0491	0.0654	0.0818	0.0981	0.1145	0.1308	0.1472
GOV3	0.0215	0.0430	0.0494	0.0645	0.0860	0.1076	0.1291	0.1506	0.1721	0.1936
GOV4	0.0155	0.0310	0.0355	0.0465	0.0620	0.0775	0.0929	0.1084	0.1239	0.1394
GOV5	0.0159	0.0319	0.0366	0.0478	0.0637	0.0797	0.0956	0.1115	0.1274	0.1434
GOV6	0.0124	0.0248	0.0285	0.0372	0.0496	0.0621	0.0745	0.0869	0.0993	0.1117
ECO1	0.0420	0.0373	0.0359	0.0326	0.0280	0.0233	0.0186	0.0140	0.0093	0.0047
ECO2	0.0620	0.0551	0.0531	0.0482	0.0413	0.0344	0.0275	0.0207	0.0138	0.0069
ECO3	0.0367	0.0326	0.0314	0.0285	0.0245	0.0204	0.0163	0.0122	0.0081	0.0041
ECO4	0.0584	0.0519	0.0500	0.0454	0.0389	0.0324	0.0259	0.0194	0.0130	0.0065
ECO5	0.0392	0.0349	0.0336	0.0305	0.0262	0.0218	0.0174	0.0131	0.0087	0.0044
SOC1	0.0646	0.0574	0.0553	0.0502	0.0431	0.0359	0.0287	0.0215	0.0143	0.0072
SOC2	0.0557	0.0495	0.0477	0.0433	0.0371	0.0309	0.0247	0.0186	0.0124	0.0062
SOC3	0.0396	0.0352	0.0339	0.0308	0.0264	0.0220	0.0176	0.0132	0.0088	0.0044
SOC4	0.0361	0.0321	0.0309	0.0280	0.0240	0.0200	0.0160	0.0120	0.0080	0.0040
TECH1	0.0454	0.0404	0.0389	0.0353	0.0303	0.0252	0.0202	0.0151	0.0101	0.0050
TECH2	0.0372	0.0330	0.0318	0.0289	0.0248	0.0206	0.0165	0.0124	0.0083	0.0041
TECH3	0.0309	0.0274	0.0264	0.0240	0.0206	0.0171	0.0137	0.0103	0.0069	0.0034
TECH4	0.0295	0.0262	0.0253	0.0230	0.0197	0.0164	0.0131	0.0098	0.0066	0.0033
TECH5	0.0289	0.0257	0.0247	0.0225	0.0193	0.0160	0.0128	0.0096	0.0064	0.0032
TECH6	0.0268	0.0239	0.0230	0.0209	0.0179	0.0149	0.0119	0.0089	0.0060	0.0030
ENV1	0.0400	0.0356	0.0343	0.0311	0.0267	0.0222	0.0178	0.0133	0.0089	0.0044
ENV2	0.0421	0.0374	0.0360	0.0327	0.0281	0.0234	0.0187	0.0140	0.0093	0.0047
ENV3	0.0304	0.0270	0.0260	0.0236	0.0203	0.0169	0.0135	0.0101	0.0068	0.0034
ENV4	0.0409	0.0364	0.0350	0.0318	0.0273	0.0227	0.0182	0.0136	0.0091	0.0045
ENV5	0.0320	0.0285	0.0274	0.0249	0.0214	0.0178	0.0142	0.0107	0.0071	0.0036
L&E1	0.0173	0.0154	0.0149	0.0135	0.0116	0.0096	0.0077	0.0058	0.0039	0.0019
L&E2	0.0194	0.0172	0.0166	0.0151	0.0129	0.0107	0.0086	0.0064	0.0043	0.0021
L&E3	0.0181	0.0161	0.0155	0.0140	0.0120	0.0100	0.0080	0.0060	0.0040	0.0020
L&E4	0.0175	0.0155	0.0150	0.0136	0.0117	0.0097	0.0078	0.0058	0.0039	0.0019
L&E5	0.0093	0.0083	0.0080	0.0072	0.0062	0.0052	0.0041	0.0031	0.0021	0.0010

Global preference weight of the smart city development barriers based on sensitivity analysis is shown in Fig. 4.

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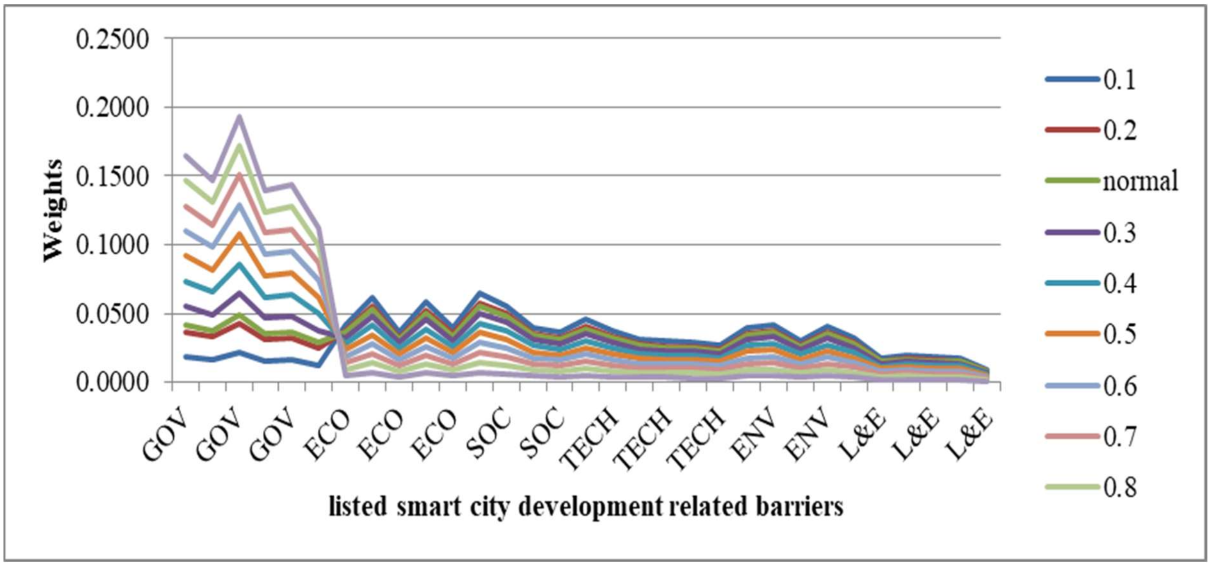

Fig. (4): Sensitivity Analysis of Barriers to Smart City Development

From Fig. 4, insignificant changes can be noticed in the global weights of barriers, and thus, the proposed framework is robust enough to deal with human subjectivity and uncertainty in data under fuzzy conditions.

7- Discussions

According to Table 6, the categories of barriers follow the order in priority as - Governance (GOV) - Economic (ECO) - Technology (TECH) - Social (SOC) - Environmental (ENV) - Legal and Ethical (L&E). Governance (GOV) categories of barriers obtain the first rank. The implementation of smart city is highly context dependent (nations, government etc.) (Weisi and Ping, 2014). Governance is one of key concerns in developing an efficient smart cities network. Thus, there is a higher need of better governance to manage several cities initiatives effectively (Chourabi et al., 2012). Within this category, 'Political instability (GOV3)' obtains the highest priority. Letaifa (2015) suggested that a smart city vision obstructed by political

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instability. Thus, leaders and practitioners should have a clear vision of the future; and make long-term plans, which could be only possible by political leadership and stability. 'Lack of cooperation and coordination between city's operational networks (GOV1)' is ranked after GOV3. There is a high need to promote cooperation and coordination between local authorities i.e. city's operational networks. 'Unclear IT management vision (GOV2)' comes next in the priority list. Chourabi et al. (2012) suggested that the integration of IT with development projects is crucial in smart city context. Next is 'Poor private-public participation (GOV5)' in this category. It means that policymakers should make efforts to promote private-public participations and investments for better governance in developing a smart city (Lee et al., 2014). 'Lack of trust between governed and government (GOV4)' comes after GOV5 according to their priority. Various researchers suggested that privacy and security issues are major concerns to develop trust between governed and government in the smart cities context. Khan et al. (2017) suggested in their research that user participation is crucial in managing smart cities data privacy and security related concerns to improve trust between governed and government. Finally, the 'Lack of developing a common information system model (GOV6)' stands last in the list. It means that common information system is modelled to collect city data to make meaningful decisions or actions in smart cities context.

Economic (ECO) category acquires second place among other barrier categories. Smart cities will require huge infrastructure, modern technologies, based on massive interconnected networks of sensors, screens, cameras, smart devices, smart grid etc. to analyse data and or information. Guy et al. (2011) concluded that infrastructure's development depends on government regulations and financial resources availability. This particular category has five specific barriers - 'Lack of competitiveness (ECO2)' obtains the utmost importance. This implies that urban

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areas need to be managed in such a way that leads to higher economic competitiveness, enhanced social security and ecological sustainability (Monzon, 2015). However, the government fails to do that. Following this, the next is 'Global economy volatility (ECO4)' barrier in the list. Global economy volatility can influence the subsidies provided, and results in higher/lower greenhouse gas emissions. Subsequently, 'High IT infrastructure and intelligence deficit (ECO1)' shows that huge infrastructure and intelligent/smart systems are required to develop smart cities. Nevertheless, it requires a lot of funds. The 'Higher operational and maintenance cost (ECO5)' barrier is next in terms of priority. Thus, technologists and practitioners must focus improving efficiency of the system for refining its sustainability (Mohanty et al., 2016). Finally, 'Cost of IT training and skills development (ECO3)' barrier is the last in the priority sequence i.e. smart city development requires higher IT training and skills, which is usually very costly.

Technology (TECH) acquired the third importance level among all the categories. Smart cities development needs higher research and technological innovations. There are different technological developments related to the IoT and Cloud computing in smart cities (Li et al., 2015; Petrolo et al., 2017; Whitmore et al., 2015). Li et al. (2014) and Whitmore et al. (2015) quoted in their research that IoT technologies will play key role in making cities more efficient and improving the lives of citizens. In this particular category, 'Lacking technological knowledge among the planners (TECH1)' barrier holds the highest priority. In respect to developing a smart city, it requires technological knowledge among the planners (Letaifa et al., 2015), as 'Lack of access to technology (TECH2)' barrier comes next to TECH1. Monzon (2015) suggested that a majority of the population living in these cities lack the access to technology. Hence, policymakers should make available the necessary technology and arrange training programs to educate the citizens for its

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accurate usage. Next, 'Privacy and security issues (TECH3)' comes in this category of barriers to smart city development. Many researchers highlighted the privacy and security issues in smart cities context (Elmaghraby et al., 2014; Belanche-Gracia et al., 2015; van Zoonen, 2016; Zhang et al., 2017). 'System failures issues (TECH4)' barrier comes next. Colding and Barthel (2017) suggested smart city network is highly vulnerable so as provide ample room for cyber-attacks of different kinds and other forms of incidents such as industrial espionage, terrorists, equipment failures, worm infestations and natural disasters. Next to this is 'Integration and convergence issues across IT networks (TECH5)' barrier to smart city development. Smart cities require various heterogeneous components to communicate, but in designing, a flexible interface to integrate these heterogeneous components is challenging. Cyber physical networks need to be integrated and supported for an effective data exchange and analysis in smart cities environment. Finally, 'Poor data availability and scalability (TECH6)' is last in the list. Santana et al. (2017) suggested that policy planners should address the issues related to data quality and its scalability in smart city context. Janssen et al. (2017) and Pereira et al. (2017) revealed in their research that big open data initiatives can help in providing real-time weather forecast, pollution and traffic management, creating transparency, better decision and policy-making and crisis management etc., and contribute to enhance the delivery of public value in smart city contexts.

Social (SOC) category of barriers occupies next place in the main priority list. There are several social concerns in developing of smart cities, such as public health and safety, education, and hospital facilities (Solanas et al. 2014). Policymakers need to deal with the social challenges in smart cities development. Colding and Barthel (2017) quoted that there are multiple socio-economic challenges with massive demographic transition; detrimental environmental impacts may also follow unless

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adequate measures are taken. This category has four specific barriers to smart city development. ‘Lack of involvement of citizens (SOC1)’ is the top ranked barrier in this category. This could be validated from the research of Yang and Callahan (2007) that citizens are often criticized due to their low interest and participation. In this sense, policymakers should encourage citizens to contribute in decision-making processes for a sustainable city. Afterwards, ‘Low awareness level of community (SOC2)’ barrier comes in this category. It means that community engagement is very important for planning and implementing smart cities initiatives. Next to this is ‘Geographical diversification problems (SOC3)’ barrier to smart cities development. In India, with a high geographical diversity, needs large amount of data to analyse urban issues and other geographical processes (Batty, 2012; Liu et al., 2016). Finally, ‘Degree of inequality (SOC4)’ is last in the hierarchy list of barriers to smart cities development. Therefore, inequalities among the citizens must be reduced to plan smart cities initiatives.

Environmental (ENV) category of barriers occupies fifth place in the priority list. Thus, practitioners, policymakers and citizens must focus to observe various ecological parameters like air pollution, temperature, vibrations, and noise and make humans consume less energy and water, and even reduce greenhouse gas emissions etc. (Colding and Barthel, 2017). This category has five specific barriers. ‘Growing population problems (ENV2)’ is at the top ranking. In India, the urbanisation is growing rapidly, and cities are likely to expand to 600 million by 2030. Higher population needs more resources to fulfil their requirements (Albino et al., 2015). Subsequently, ‘Carbon emissions effect (ENV4)’ is the next to come in this category. Sadorsky (2014) pointed out that growing urbanization leads to higher carbon emissions and results in lower sustainability. ‘Lacking ecological view in behaviour (ENV1)’ comes next. It means that a holistic approach should be adapted to promote

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ecological view in behaviour in citizens. Next to this is 'Degradation of resources (ENV5)' to smart cities development. Finally, 'Lack of sustainability considerations (ENV3)' is at the end in the list. Policy planners are suggested to include sustainability aspects while designing smart city networks for higher ecological benefits (Luthra et al., 2015).

Legal and Ethical (L&E) category of barriers holds the last place in priority list. Kitchin (2015) quoted that there are several social, ethical and legal issues linked to a smart city initiative. Within this particular category, 'Lacking standardization (L&E2)' barrier is ranked first. Clearly, there is a lack of standards and policy directions on efficient applicability and managing of IoT based networks (Weber, 2013; Perera et al., 2014; Zanella et al., 2014; Weber and Studer, 2016). 'Issues of openness of data (L&E3)' comes next to the list. Rathore et al. (2016) identified the issues of openness of data are crucial in the smart city agenda. Enabling openness of real time data will help the government authorities as well as citizens. The next barrier i.e. 'Lack of transparency and liability (L&E4)' indicates that higher public involvement and superior transparency in governance is critical in smart cities development (Kandpal et al., 2017). Next barrier in this list is 'Cultural issues (L&E1)' to smart cities development. Last in the priority list is 'Lack of regulatory norms, policies and directions (L&E5)'. Well-defined regulating norms, polices and directions are needed that help in keeping the user-friendliness to the data users and monitoring all the stakeholders and parties being a part of the system.

Further, we identified the global ranking of barriers to smart city development. According to global ranking of barriers, 'Lack of involvement of citizens (SOC1)'; 'Lack of competitiveness (ECO2)'; 'Global economy volatility (ECO4)'; 'Political instability (GOV3)' and 'Low awareness level of community (SOC2)' have been recognized as top five barriers to smart cities development in Indian context.

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8- Conclusion

Smart city development is getting considerable recognition in systematic literature and international policies in the last two decades. The present research seeks to recognise and prioritise barriers linked to smart city development to help policymakers in improving their sustainability in Indian context. In this work, we used fuzzy AHP for knowing the importance of the potential barriers under fuzzy surroundings.

A comprehensive review of keywords across various literature surveys fetched us 31 key barriers to smart cities development. These barriers were also confirmed further through experts. We categorised these barriers into six key categories with experts' consultation.

'Governance' is documented as the most significant category of barriers for smart city development followed by barriers related to 'Economic; 'Technology'; 'Social'; 'Environmental' and 'Legal and Ethical' categories. The relative and global preference weights of specific barriers are also determined. The sensitivity analysis is performed to verify the stability of the findings obtained in this study. This research is useful to the government and policymakers for eradicating the potential interferences in smart city development initiatives in developing countries like India.

References

- Aijaz, R. (2016). Challenge of making smart cities in India. IFRI Center of Asian Studies. Asie Visions. 1-34. Available at: https://www.ifri.org/sites/default/files/atoms/files /av87_smart_cities_india_aijaz_0.pdf (Last accessed: January 24, 2018).
- Alawadhi, S., Aldama-Nalda, A., Chourabi, H., Gil-García, J., Leung, S., Mellouli, S., Nam, T., Pardo, T. A., Scholl, H. J. and Walker, S. (2012). Building understanding of smart city initiatives. Electronic Government, 40-53.

E-ISSN 2976-9361

https://doi.org/10.59992/IJCI.2023.v2n7p2

- Albino, V., Berardi, U. and Dangelico, R. M. (2015). Smart cities: Definitions, dimensions, performance, and initiatives. Journal of Urban Technology, 22(1), 3-21.
- Angelidou, M. (2015). Smart cities: A conjuncture of four forces. Cities, 47, 95-106.
- Bakıcı, T., Almirall, E. and Wareham, J. (2013). A smart city initiative: The case of Barcelona. Journal of the Knowledge Economy, 4(2), 135-148.
- Ballon, P., Glidden, J., Kranas, P., Menychtas, A., Ruston, S. and Van Der Graaf, S. (2011). Is there a need for a cloud platform for European smart cities? In eChallenges e-2011 Conference Proceedings on IIMC International Information Management Corporation, 1-7.
- Balta-Ozkan, N., Davidson, R., Bicket, M. and Whitmarsh, L. (2013). Social barriers to the adoption of smart homes. Energy Policy, 63, 363-374.
- Batty, M. (2012). Smart cities, big data. Centre for Advanced Spatial Analysis. Available at: http://www.spatialcomplexity.info/files/2014/03/BATTY-TECHNION1.pdf (Last accessed: January 19, 2018).
- Belanche-Gracia, D., Casalo-Arino, L. V. and Pérez-Rueda, A. (2015). Determinants of multi-service smartcard success for smart cities development: A study based on citizens' privacy and security perceptions. Government Information Quarterly, 32(2), 154-163.
- Bhattacharya, S., Rathi, S., Patro, S.A., Tepa, N. (2015). Reconceptualising smart cities: A reference framework for India. CSTEP. Available at: http://niti.gov.in/writereaddata/files/document_publication/CSTEP%20Report%20 Smart%20Cities%20Framework.pdf (Last accessed: December 16, 2017).
- Bloomberg Philanthropies (2017). India smart cities mission. Available at: https://www.bloomberg.org/program/government-innovation/india-smart-cities-mission (Last accessed: August 02, 2017).
- Chang, D. Y. (1996). Applications of the extent analysis method on fuzzy AHP. European Journal of Operational Research, 95(3), 649-655.
- China Daily (2013). 'Smart city' takes shape in Xinjiang. Available at: http://www.chinadaily.com.cn/ china/2012cpc /2012-11/14/content_15925234.htm (Last accessed: December 23, 2017).
- Chourabi, H., Nam, T., Walker, S., Gil-Garcia, J. R., Mellouli, S., Nahon, K., Pardo, T. A. & Scholl, H. J. (2012). Understanding smart cities: An integrative framework. 45th Hawaii International Conference on System Science, 2289-2297.

E-ISSN 2976-9361
https://doi.org/10.59992/IJCI.2023.v2n7p2

- Colding, J. and Barthel, S. (2017). An urban ecology critique on the “Smart City” model. Journal of Cleaner Production, 164, 95-101.
- Cruz-Jesus, F., Oliveira, T., Bacao, F., & Irani, Z. (2017). Assessing the pattern between economic and digital development of countries. Information Systems Frontiers, 19(4), 835-854.
- Datta, A. (2016). Three big challenges for smart cities and how to solve them. The Conversation. Available at: http://theconversation.com/three-big-challenges-for-smart-cities-and-how-to-solve-them-59191 (Last accessed: December 15, 2017).
- Djahel, S., Salehie, M., Tal, I. and Jamshidi, P. (2013). Adaptive traffic management for secure and efficient emergency services in smart cities. 2013 IEEE International Conference on Pervasive Computing and Communications Workshops, 340-343.
- Dubois, D. and Prade, H. (1979). Operations in a fuzzy-valued logic. Information and Control, 43(2), 224-240.
- Elmaghraby, A. S. and Losavio, M. M. (2014). Cyber security challenges in smart cities: Safety, security and privacy. Journal of Advanced Research, 5(4), 491-497.
- Elmangoush, A., Coskun, H., Wahle, S. and Magedanz, T. (2013). Design aspects for a reference M2M communication platform for smart cities. 9th International Conference on Innovations in Information Technology, 204-209.
- Ferrara, R. (2015). The smart city and the green economy in Europe: A critical approach. Energies, 8(6), 4724-4734.
- Glaeser, E.L., Resseger, M. and Tobio, K. (2009). Inequality in cities. Journal of Regional Science, 49(4), 617-646.
- Gluhak, A. (2017). Seven challenges for scaling IoT enabled smart cities. IoT UK, Available at: https://iotuk.org.uk/seven-challenges-for-scaling-iot-enabled-smart-cities/ (Last accessed: December 16, 2017).
- Govindan, K., Diabat, A. and Shankar, K. M. (2015). Analyzing the drivers of green manufacturing with fuzzy approach. Journal of Cleaner Production, 96, 182-193.
- Govindan, K., Mangla, S.K. and Luthra, S., (2017). Prioritising indicators in improving supply chain performance using fuzzy AHP: insights from the case example of four Indian manufacturing companies. Production Planning & Control, 28(6-8), 552-573.

- Guy S, Medd W, Marvin S, and Moss T (Eds.) (2011). Urban transitions: Intermediaries and the governance of socio-technical networks. Earth Scan, London.
- Harputlugil, T., Prins, M., Gultekin, T. and Topcu, I. (2011). Conceptual framework for potential implementations of Multi Criteria Decision Making (MCDM) methods for design quality assessment. In Management and Innovation for a Sustainable Built Environment, Amsterdam, The Netherlands, June 20–23, ISBN: 9789052693958.
- Hernández-Muñoz, J. M., Vercher, J. B., Muñoz, L., Galache, J. A., Presser, M., Gómez, L. A. H. and Pettersson, J. (2011). Smart cities at the forefront of the future internet. In The Future Internet Assembly, 447-462. Springer, Berlin, Heidelberg.
- IET (2017). Smart cities – Time to involve the people. The Institution of Engineering and Technology. Available at: http://www.theiet.org/sectors/thought-leadership/future-cities/articles/smart-citiesinvolve.cfm?utm_source=redirect&utm_medium=any&utm campaign=smartcities (Last accessed: December 16, 2017).
- Ishizaka, A. and Labib, A. (2009). Analytic hierarchy process and expert choice: Benefits and limitations. OR Insight, 22(4), 201-220.
- Janssen, M., Konopnicki, D., Snowdon, J. L. and Ojo, A. (2017). Driving public sector innovation using big and open linked data (BOLD). Information Systems Frontiers, 19(2), 189-195.
- Junior, F. R. L., Osiro, L. and Carpinetti, L. C. R. (2014). A comparison between fuzzy AHP and fuzzy TOPSIS methods to supplier selection. Applied Soft Computing, 21, 194-209.
- Kar, A. K. (2015). A hybrid group decision support system for supplier selection using analytic hierarchy process, fuzzy set theory and neural network. Journal of Computational Science, 6, 23-33.
- Kandpal, V., Kaur, H. and Tyagi, V. (2017). Smart city projects in India: Issues and challenges.
- Khan, Z., Pervez, Z. and Abbasi, A. G. (2017). Towards a secure service provisioning framework in a smart city environment. Future Generation Computer Systems, 77, 112-135.
- Kitchin, R. (2015). The promise and peril of smart cities. Computers and Law: The Journal of the Society for Computers and Law, 26(2), 1-5.
- Kogan, N. and Lee, K.J. (2014). Exploratory research on success factors and challenges of smart city projects. MSc Thesis, Kyung Hee University, Seoul, South Korea.

IJCI, VSRP Publishing, UK
https://ijci.vsrp.co.uk
E-ISSN 2976-9361
https://doi.org/10.59992/IJCI.2023.v2n7p2

- Komninos, N., Pallot, M. and Schaffers, H. (2013). Special issue on smart cities and the future Internet in Europe. Journal of the Knowledge Economy, 4(2), 119-134.
- Koo, C., Ricci, F., Cobanoglu, C. and Okumus, F. (2017). Special issue on smart, connected hospitality and tourism. Information Systems Frontiers, 19(4), 699-703.
- Koppenjan, J. F. and Enserink, B. (2009). Public–private partnerships in urban infrastructures: Reconciling private sector participation and sustainability. Public Administration Review, 69(2), 284-296.
- Lazaroiu, G. C. and Roscia, M. (2012). Definition methodology for the smart cities model. Energy, 47(1), 326-332.
- Lee, J. and Lee, H. (2014). Developing and validating a citizen-centric typology for smart city services. Government Information Quarterly, 31, S93-S105.
- Lee, J. H., Hancock, M. G. and Hu, M. C. (2014). Towards an effective framework for building smart cities: Lessons from Seoul and San Francisco. Technological Forecasting and Social Change, 89, 80-99.
- Lee, J. H., Phaal, R. and Lee, S. H. (2013). An integrated service-device-technology roadmap for smart city development. Technological Forecasting and Social Change, 80(2), 286-306.
- Letaifa, S. B. (2015). How to strategize smart cities: Revealing the SMART model. Journal of Business Research, 68(7), 1414-1419.
- Li, S., Da Xu, L., and Zhao, S. (2015). The internet of things: a survey. Information Systems Frontiers, 17(2), 243-259.
- Lin, R. J. (2013). Using fuzzy DEMATEL to evaluate the green supply chain management practices. Journal of Cleaner Production, 40, 32-39.
- Liu, J., Li, J., Li, W. and Wu, J. (2016). Rethinking big data: A review on the data quality and usage issues. ISPRS Journal of Photogrammetry and Remote Sensing, 115, 134-142.
- Luthra, S., Garg, D. and Haleem, A. (2013). Identifying and ranking of strategies to implement green supply chain management in Indian manufacturing industry using Analytical Hierarchy Process. Journal of Industrial Engineering and Management, 6(4), 930-962.
- Luthra, S., Mangla, S. K. and Kharb, R. K. (2015). Sustainable assessment in energy planning and management in Indian perspective. Renewable and Sustainable Energy Reviews, 47, 58-73.

E-ISSN 2976-9361

https://doi.org/10.59992/IJCI.2023.v2n7p2

- Luthra, S., Mangla, S. K., Xu, L. and Diabat, A. (2016). Using AHP to evaluate barriers in adopting sustainable consumption and production initiatives in a supply chain. International Journal of Production Economics, 181, 342-349.
- Mckinsey Report (2018). Combating the challenges of urbanization in emerging markets: Lessons from India. Accessed from https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/combating-the-challenges-of-urbanization-in-emerging-markets-lessons-from-india on 22th April 2018.
- Mandal, T. (2016). Smart cities must be smart about emissions. India Climate Dialogue, Accessed from http://indiaclimatedialogue.net/2016/02/26/smart-cities-must-be-smart-about-emissions/ on 15th December 2017.
- Mangla, S. K., Govindan, K. and Luthra, S. (2017). Prioritizing the barriers to achieve sustainable consumption and production trends in supply chains using fuzzy Analytical Hierarchy Process. Journal of Cleaner Production, 151, 509-525.
- Mangla, S.K., Govindan, K. and Luthra, S., (2016). Critical success factors for reverse logistics in Indian industries: a structural model. Journal of Cleaner Production, 129, 608-621.
- Mangla, S. K., Kumar, P. and Barua, M. K. (2015). Risk analysis in green supply chain using fuzzy AHP approach: A case study. Resources, Conservation and Recycling, 104, 375-390.
- Mohanty, S. P., Choppali, U. and Kougianos, E. (2016). Everything you wanted to know about smart cities: The internet of things is the backbone. IEEE Consumer Electronics Magazine, 5(3), 60-70.
- Monzon, A. (2015). Smart cities concept and challenges: Bases for the assessment of smart city projects. International Conference on Smart Cities and Green ICT Systems, 17-31.
- Mori, K. and Christodoulou, A. (2012). Review of sustainability indices and indicators: Towards a new City Sustainability Index (CSI). Environmental Impact Assessment Review, 32(1), 94-106.
- Nair, S. (2017). The too smart city. Indian Express. Available at: http://indianexpress.com/article/opinion/columns/smart-city-mission-urban-development-4721785/ (Last accessed: August 20, 2017).
- Nam, T. and Pardo, T. A. (2011). Conceptualizing smart city with dimensions of technology, people, and institutions. 12th Annual International Digital Government Research Conference: Digital Government Innovation in Challenging Times, 282-291.

E-ISSN 2976-9361

https://doi.org/10.59992/IJCI.2023.v2n7p2

- Naphade, M., Banavar, G., Harrison, C., Paraszczak, J. and Morris, R. (2011). Smarter cities and their innovation challenges. Computer, 44(6), 32-39.
- Neirotti, P., De Marco, A., Cagliano, A. C., Mangano, G. and Scorrano, F. (2014). Current trends in Smart City initiatives: Some stylised facts. Cities, 38, 25-36.
- OCED (2015). The path to happiness lies in good health and a good job, the Better Life Index shows. The Organisation for Economic Co-operation and Development (OECD), Paris, France. Available at: http://www.oecd.org/newsroom/the-path-to-happiness-lies-in-good-health-and-a-good-job-the-better-life-index-shows.htm (Last accessed: January 24, 2018).
- Ordoobadi, S. M. (2010). Application of AHP and Taguchi loss functions in supply chain. Industrial Management & Data Systems, 110(8), 1251-1269.
- Paskaleva, K. A. (2011). The smart city: A nexus for open innovation? Intelligent Buildings International, 3(3), 153-171.
- Pereira, G. V., Macadar, M. A., Luciano, E. M., & Testa, M. G. (2017). Delivering public value through open government data initiatives in a Smart City context. Information Systems Frontiers, 19(2), 213-229.
- Perera, C., Zaslavsky, A., Christen, P. and Georgakopoulos, D. (2014). Sensing as a service model for smart cities supported by internet of things. Transactions on Emerging Telecommunications Technologies, 25(1), 81-93.
- Petrolo, R., Loscri, V. and Mitton, N. (2017). Towards a smart city based on cloud of things, a survey on the smart city vision and paradigms. Transactions on Emerging Telecommunications Technologies, 28(1), 29-31.
- Platts, K. W. and Gregory, M. J. (1990). Manufacturing audit in the process of strategy formulation. International Journal of Operations & Production Management, 10(9), 5-26.
- Prakash, C. and Barua, M. K. (2015). Integration of AHP-TOPSIS method for prioritizing the solutions of reverse logistics adoption to overcome its barriers under fuzzy environment. Journal of Manufacturing Systems, 37, 599-615.
- Rathore, M. M., Ahmad, A., Paul, A. and Rho, S. (2016). Urban planning and building smart cities based on the internet of things using big data analytics. Computer Networks, 101, 63-80.
- Saaty, T. L. (1980). The analytic hierarchy process: planning. Priority setting. Resource Allocation. MacGraw-Hill, New York International Book Company, 287.

- Sadorsky, P. (2014). The effect of urbanization on CO2 emissions in emerging economies. Energy Economics, 41, 147-153.
- Sahoo, S., Dhar, A. and Kar, A. (2016). Environmental vulnerability assessment using Grey Analytic Hierarchy Process based model. Environmental Impact Assessment Review, 56, 145-154.
- Santana, E. F. Z., Chaves, A. P., Gerosa, M. A., Kon, F. and Milojicic, D. S. (2017). Software platforms for smart cities: Concepts, requirements, challenges, and a unified reference architecture. ACM Computing Surveys, 50(6), 78.
- Schuurman, D., Baccarne, B., De Marez, L. and Mechant, P. (2012). Smart ideas for smart cities: Investigating crowdsourcing for generating and selecting ideas for ICT innovation in a city context. Journal of Theoretical and Applied Electronic Commerce Research, 7(3), 49-62.
- Scuotto, V., Ferraris, A. and Bresciani, S. (2016). Internet of Things: Applications and challenges in smart cities: A case study of IBM smart city projects. Business Process Management Journal, 22(2), 357-367.
- Solanas, A., Patsakis, C., Conti, M., Vlachos, I. S., Ramos, V., Falcone, F., Postolache, O., Martinez-Balleste, P.A., Pietro, R.D., Perrea, D.N. and Martinez-Balleste, A. (2014). Smart health: A context-aware health paradigm within smart cities. IEEE Communications Magazine, 52(8), 74-81.
- Tachizawa, E. M., Alvarez-Gil, M. J. and Montes-Sancho, M. J. (2015). How "smart cities" will change supply chain management. Supply Chain Management: An International Journal, 20(3), 237-248.
- The Indian Express (2016). Quality of life: Which is the best Indian city to live in? Available at:http://indianexpress.com/article/india/india-news-india/where-to-live-in-india-which- city-offers-the-best-quality-of-living-2891060/ (Last accessed: January 24, 2018).
- UNFPA (2008). State of World population 2007: Unleashing the potential of urban growth. United Nations Population Fund (UNFPA), New York, 2008.
- van Zoonen, L. (2016). Privacy concerns in smart cities. Government Information Quarterly, 33(3), 472-480.
- Voss, C., Tsikriktsis, N., and Frohlich, M. (2002). Case research in operations management. International Journal of Operations & Production Management, 22(2), 195-219.
- Washburn, D., Sindhu, U., Balaouras, S., Dines, R. A., Hayes, N. M. and Nelson, L.E. (2010).

E-ISSN 2976-9361

https://doi.org/10.59992/IJCI.2023.v2n7p2

Helping CIOs understand “Smart City” initiatives: Defining the smart city, its drivers, and the role of the CIO. Forrester Research, MA, Cambridge.

- Weber, R. H. (2013). Internet of things–governance quo vadis? Computer Law & Security Review, 29(4), 341-347.
- Weber, R. H. and Studer, E. (2016). Cyber security in the Internet of Things: Legal aspects. Computer Law & Security Review, 32(5), 715-728.
- Weisi, F. U. and Ping, P. E. N. G. (2014). A discussion on smart city management based on meta-synthesis method. Management Science and Engineering, 8(1), 68-72.
- Whitmore, A., Agarwal, A., & Da Xu, L. (2015). The Internet of Things—A survey of topics and trends. Information Systems Frontiers, 17(2), 261-274.
- Yang, K. and Callahan, K. (2007). Citizen involvement efforts and bureaucratic responsiveness: Participatory values, stakeholder pressures, and administrative practicality. Public Administration Review, 67(2), 249-264.
- Yoon, A. (2015). How Smart Cities Enable Urban Sustainability. Online available at: https://www.triplepundit. com/2015/08/smart-cities-enable-urban-sustainability/ (Last accessed: December 15, 2017).
- Yigitcanlar, T. (2015). Smart cities: An effective urban development and management model?. Australian Planner, 52(1), 27-34.
- Zadeh, L. A. (1965). Information and control. Fuzzy Sets, 8(3), 338-353.
- Zanella, A., Bui, N., Castellani, A., Vangelista, L. and Zorzi, M. (2014). Internet of things for smart cities. IEEE Internet of Things journal, 1(1), 22-32.
- Zhang, K., Ni, J., Yang, K., Liang, X., Ren, J. and Shen, X. S. (2017). Security and privacy in smart city applications: Challenges and solutions. IEEE Communications Magazine, 55(1), 122-129.
- Zygiaris, S. (2013). Smart city reference model: Assisting planners to conceptualize the building of smart city innovation ecosystems. Journal of the Knowledge Economy, 4(2), 217-231.

E-ISSN 2976-9361

https://doi.org/10.59992/IJCI.2023.v2n7p2