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ScienceDirect

Energy Procedia 141 (2017) 211–215

Energy Procedia

www.elsevier.com/locate/procedia

4th International Conference on Power and Energy Systems Engineering, CPESE 2017, 25-29 September 2017, Berlin, Germany

Evaluation of Sustainability Indicators in Smart Cities for India Using MCDM Approach

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Abstract

A smart city is defined as a sustainable and efficient city center providing high quality of life by optimally using its resources. Managing its resources especially energy is a very crucial factor owing to the complexity of various interlinked parameters. In this paper, the importance of various criteria for sustainability in a smart city are determined using fuzzy and fuzzy-AHP method. The sustainability indicators for designing a smart city in a developing country has been identified. DEA:AR-CCR model is adopted to determine the relative efficiency of each of the sustainability indicators for a smart city in the context of input and output criteria. The decomposition efficiency measures clearly highlight which sustainability indicator the country needs to focus based on the importance of the input criteria to achieve the desired outputs. It was found policy makers and administrators have to design policies for economic development (0.85) and energy (0.82) for achieving economic prosperity of the nation.

Peer-review under responsibility of the scientific committee of the 4th International Conference on Power and Energy Systems Engineering.

Keywords: sustainability indicators; smart city; fuzzy AHP DEA; energy; economy

1. Introduction

The Smart Cities Mission of Government of India calls for catalysing the creation of similar Smart Cities in various regions and parts of the country. The term 'smart city' has been coined differently based on the context. Albino et al. [1] while comparing the various definitions of a smart city has identified the main dimensions of a smart city along with metrics for measuring urban smartness. A review on energy planning and management for smart cities was done by Calvillo et al. [2]. Spickermann [3] used Delphi technique to redesign the infrastructure of the city and convert them into a smart city. The research suggest that mobility factor plays a vital role in developing countries in order to make their cities smart. Debnath et al. [4] have arrived at a framework to benchmark cities' smartness based on their transportation system. Giffinger et al. [5] have used intangible indicators namely economy, mobility, environment, people, living and governance to measure smartness and have ranked 70 European cities. They have also highlighted how the cities can be positioned with the ranking [6]. Not just smartness but sustainable

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1876-6102
Peer-review under responsibility of the scientific committee of the 4th International Conference on Power and Energy Systems Engineering.
10.1016/j.egypro.2017.11.094

smartness of cities is the need of the hour because of environmental challenges and population expansion in the cities [7]. Sustainability indicators play a vital role in measuring the smartness of a city [8,9].

Various techniques can be used to identify the importance of sustainable indicators like fuzzy, analytical hierarchy process (AHP), data envelopment analysis (DEA). Galiardi et al. [10] and Lazaroiu and Roscia [11] have used fuzzy logic to determine the weights of each of the sustainable indicators. Lee et al. [12] used multi-case study approach to build smart cities. This study suggests to use more integrated approach for selecting suitable sustainable indicators to make a city smart. Lombardi et al. [13] have used ANP to model the smart city performance. Auci et al. [14] have used a stochastic frontier function for maximizing the output function namely urban productivity / urban efficiency. They have used the efficiency score for ranking of European cities. An integrated fuzzy AHP DEA has been used by Lee et al. [15, 16] for finding the relative efficiency of hydrogen energy technologies. In this paper, it is proposed to do a similar methodology along with assurance region constraints - fuzzy AHP DEA:AR-CCR MCDM model which has not been explored in the context of ranking sustainability indicators of a smart city. Various input and output criteria such as energy, economy, environment, society, mobility, quality of life, self-sustenance for prosperity of the nation will be analysed.

2. Methodology

In this paper three input criteria and four output criteria are selected. The input criteria considered in this paper are mobility (MO), economy (EC), environment (EV), society (SO), energy (EN). The output criteria considered are quality of life (QL), self-sustenance (SS) and economic prosperity (EP). 20 sustainable indicators have been identified from the review. The methodology proposed by Lee et al. [15, 16] has been adopted for determining the importance of criteria using fuzzy AHP. Sixteen experts were identified in the relevant area and they were asked to rank the input and output criteria. Then pair wise comparison of each expert was carried out using the triangular fuzzy logic (TFN) scale. Fuzzy AHP helps to get the relative weights for input and output criteria. DEA helps to find the relative efficiency of various sustainable indicators. Charnes et al. [17] DEA method was adopted in this paper to estimate the relative efficiency. AR (assurance region)-CCR model was adopted to avoid the zero effect.

3. Results and Discussion

The relative importance of the input output criteria was obtained from experts. The consistency (CI) and the consistency ratio (CR) for each of the experts was found to be within the acceptable range (CR ≤ 0.1). The average importance of the criteria using fuzzy and fuzzy AHP are given in Table 1.

Table 1. Importance of criteria using AHP and fuzzy AHP: A comparison

	Criteria	AHP	Fuzzy AHP
Input criteria	Mobility (MO)	0.204555	0.206967
	Economy (EC)	0.124948	0.145143
	Environment (EV)	0.159093	0.113329
	Society (SO)	0.219323	0.242687
	Energy (EN)	0.292081	0.291873
Output criteria	Quality of Life (QL)	0.223534	0.19131
	Self-Sustenance (SS)	0.38112	0.418916
	Economic prosperity	0.395346	0.389775

It is found from the table that energy is a very important criterion as indicated by both AHP and fuzzy AHP method. This is followed by society. With reference to the output criteria it is found that economic prosperity is found to be very important with regard to AHP while self-sustenance is found to be an important criterion from fuzzy AHP method. The experts were requested to rate each of the 20 sustainability indicators, the relationship it has on the input criteria for obtaining the desired output. The DEA model was run considering the assurance region using criteria multipliers. The decomposition efficiency of the indicators is given in Table. 2.

Table 2. Efficiency Decomposition of sustainable indicators

		Efficiency	MO	EC	EV	SO	EN	QL	SS	EP	Rank
1	Poverty Alleviation	0.94	0.05	0.50	0.05	0.37	0.09	0.09	0.19	0.52	4
2	Food Security	0.89	0.02	0.53	0.11	0.39	0.07	0.07	0.17	0.56	6
3	Education Facility	0.99	0.05	0.40	0.10	0.40	0.07	0.07	0.20	0.57	3
4	Harmonious Living	0.66	0.14	0.53	0.12	0.67	0.07	0.07	0.34	0.31	12
5	GDP per capita	0.80	0.10	0.61	0.15	0.30	0.10	0.10	0.08	0.31	10
6	Employment	0.82	0.09	0.60	0.09	0.37	0.06	0.06	0.16	0.53	9
7	Corruption	0.41	0.13	0.85	0.26	1.07	0.14	0.14	0.09	0.20	19
8	Saving Potential	1.00	0.10	0.28	0.06	0.48	0.08	0.08	0.16	0.51	1
9	Pollution [incl Noise]	0.92	0.09	0.44	0.20	0.24	0.12	0.12	0.13	0.24	5
10	Drainage/ Sanitation /Cleanliness	0.54	0.12	0.52	0.38	0.76	0.08	0.08	0.38	0.27	15
11	Water Quality/Availability	0.51	0.08	0.64	0.30	0.79	0.16	0.16	0.30	0.38	16
12	Population	0.44	0.13	0.98	0.25	0.73	0.17	0.17	0.14	0.58	18
13	Mass Transport	0.64	0.23	0.76	0.20	0.21	0.16	0.16	0.14	0.57	14
14	Non motorized transport [Carbon Footprint]	0.99	0.14	0.39	0.17	0.17	0.13	0.13	0.17	0.56	2
15	Road Conditions	0.34	0.37	1.36	0.28	0.75	0.19	0.19	0.35	0.35	20
16	Distance of travel [Demographics of Housing]	0.49	0.35	0.64	0.27	0.59	0.18	0.18	0.14	0.24	17
17	Renewable Energy Use	0.84	0.07	0.52	0.19	0.25	0.16	0.16	0.15	0.57	8
18	Smart Housing	0.78	0.06	0.37	0.19	0.48	0.18	0.18	0.19	0.52	11
19	Automation [Iot Based]	0.84	0.09	0.53	0.08	0.39	0.09	0.09	0.19	0.55	7
20	Life Style of People	0.65	0.12	0.68	0.21	0.43	0.10	0.10	0.17	0.27	13

It is found that the capacity for an individual to judiciously use his funds will go a long way in improving the economic prosperity of the nation as indicated by the input (society=0.48) and output criteria (economic prosperity=0.51). The next important indicator is found to be non-motorized transport (walking and cycling). This will help in reducing the carbon footprint of the country and hence help in improving the economy. The third in rank is the education facility. The other important sustainability indicators are poverty alleviation, pollution, food security, automation (IoT based). The decomposition efficiency for each of the sustainability indicators with reference to the input criteria is depicted in Fig. 1. From the figure, it is clear that economy and society are very important criteria to be concentrated upon while developing the infra structure for a smart city in a developing country. Though Table 1 indicated energy to be a very important criteria yet in the context of designing and developing a smart city, economy and society plays a pivotal role followed by energy and environment. Fig. 2 represents the decomposition efficiency of the sustainability indicators with reference to the output criteria. It is found that economic prosperity takes the lead followed by self-sustenance and quality of life. The sustainability indicators were categorized based on the thematic characteristics. The average relative efficiency from DEA is given in Table. 3. It is found from the relative efficiency, economic development (0.85) needs to be concentrated upon followed by energy (0.82), environment (0.81) and basic amenities (0.80). The research clearly highlights the need for policies that focusses on energy and economy for poverty alleviation, education, food security, clean environment and employment while designing and developing a smart city.

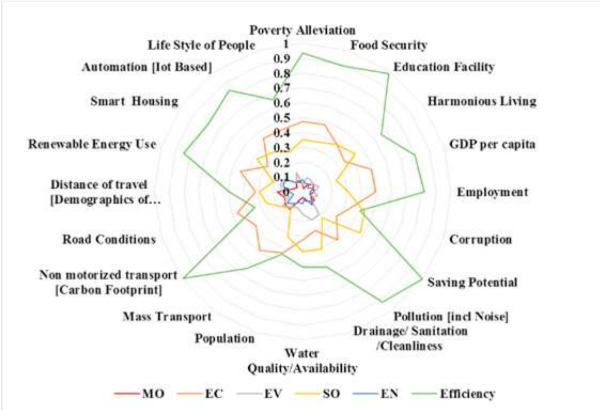

Fig. 1. Comparison of sustainability indicators for smart cities with reference to input criteria

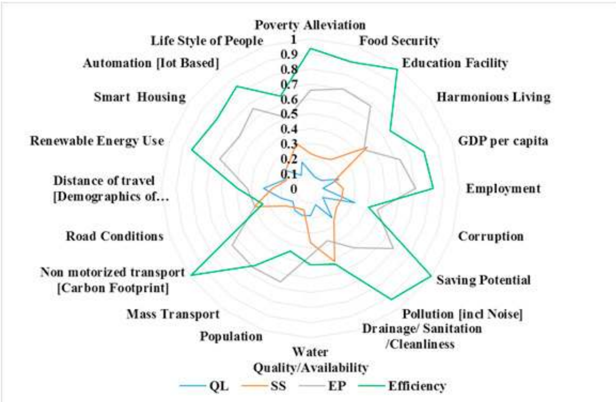

Fig. 2. Comparison of sustainability indicators for smart cities with reference to output criteria

Table 3. Importance of Sustainability Indicators based on themes

Sustainable Indicators based on Themes		Average	Sustainable Indicators based on Themes		Average
Basic Amenities			*Energy*		
Food Security	0.89		Renewable Energy Use	0.84	
Education Facility	0.99	0.80	Smart Housing	0.78	0.82
Drainage/ Sanitation /Cleanliness	0.54		Automation [Iot based]	0.84	
Demography			*Environment*		
Harmonious Living	0.66		Pollution [incl Noise]	0.92	
Population	0.44	0.58	Water Quality/Availability	0.51	0.81
Life Style of People	0.65		Non motorized transport [Carbon Footprint]	0.99	
Economic Development			*Transportation*		
Poverty Alleviation	0.94		Mass Transport	0.64	
GDP per capita	0.8	0.85	Road Conditions	0.34	0.49
Employment	0.82		Distance of travel [Demographics of Housing]	0.49	
Governance					
Corruption	0.41				
Saving Potential	1	0.70			

4. Conclusion

The requirements for a holistic smart city considering diverse criteria have been studied. Though it may be difficult to integrate all elements of the criteria yet it is crucial to identify the most influencing ones so that concentration on the vital few will result in a ripple effect. This paper considers multiple criteria simultaneously for prioritizing the sustainability indicators for the creation of a smart city. The fuzzy AHP DEA analysis reveals that policy makers need to focus on the energy and economy. This will facilitate in securing the environment, ease out mobility issues and provide a higher quality of life to its citizens. The results of this study will aid decision makers in government organizations and industries to develop and implement an energy efficient smart city at optimal cost

Acknowledgements

The authors gratefully acknowledge the support received under the Maulana Azad National Fellowship (MANF), University Grants Commission (UGC), India.

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