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INDICATOR BASED APPROACH FOR DEVELOPMENT OF SUSTAINABILITY INDEX: THE CASE OF DAVANAGERE CITY

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Abstract*— Managing urban growth has emerged as one of the most vital challenges in the twenty first century. Understanding and promoting the city sustainability through efficient resource utilization could be the proper approach for achieving sustainability in urban areas. Assessing the prevailing sustainability level is the primary step in achieving and maintaining higher levels of sustainability. Thus, development of a sustainability index for a city is the key in urban planning and its value to smart cities cannot be ignored. Different methods, techniques and instruments for urban sustainability assessment have emerged over a period of time. Amongst them, indicator-based approach to assess and improve urban sustainability is increasingly adopted. The current paper is an attempt to assess the sustainability of Davanagere City with this widely accepted indicator based approach. This approach comprises three vital dimensions of sustainability viz., environmental, social, and economical factors. After collecting the empirical data regarding all the three dimensions through a scientific sampling, the Sustainability Development Index (SDI) is computed. The result of the study reveals a significant scope to improve the prevailing SDI of the city and hence has useful policy implications in the Sustainable Development of Davanagere City in the long run.

Key words: Indicators, Sustainability, Development, Index, City

I. INTRODUCTION

In simple words Sustainability may be described as “utilization of all our resources in efficient and effective ways without compromising the present needs and at the same time conserving these resources for the future generations for meeting their own needs”. Sustainable Development (SD) with respect to urban centers concern with the balanced consumption of available energy and other resources in all the sectors of economy without straining the three important pillars of sustainability viz., Environmental, Economical, and Social. Inefficient methods of consumption of energy and other resources in any sector of the economy lead to imbalance in these three pillars resulting in affecting the SD in the long run.

Residential sector of an urban city assumes significance in view of the dominant share of utilization of energy and other resources by it. The assessment of prevailing sustainability level is primary to ensure and maintain an internal balance amongst environmental, social and economic dimensions of SD in a city. In this backdrop, indicator-based SD indices are increasingly adopted for assessing the prevailing levels of sustainability. Aiming to evaluate the SD comprehensively, such indices comprise various aspects of SD like population growth, urban infrastructure, pollution, urban waste, noise level, water consumption, mode of transportation, health infrastructure, safety, job opportunities, etc., pertaining to a city.

Thus, collection and analysis of such indicators is essential for assessing and also attaining SD of a city.

II LITERATURE REVIEW

A review of available literature revealed the availability of a few studies dealing with assessment of SD index and also energy consumption issues of urban cities.

Rahul B. Hiremath [1] et.al explained how to develop indicators with respect to energy resources available in urban areas and also type of characteristics to be considered while selecting an indicator for achieving city sustainability. For developing city sustainability design, proper policy, tools, technologies by examining resource usage and sharing of benefits in transportation,

household, commercial and industrial activities are all imperative. This paper used indicator based sustainability assessment for investigating the city sustainability and concluded that indicators play an important role in attaining the SD of a city.

Parisa Pakzad [2] et.al, dealt with development of indicators for attaining "green infrastructure" (GI) model. For this purpose, a set of questionnaire was developed based on social-cultural, economic, ecological, and health parameters. In this survey based research work, questionnaires were sent to respondents through online to their individual mail account. The questionnaire included a number of questions or statements with respect to GI sustainability; each participant was asked to give opinions/marks to each questions or statements based on their own point of view. Five point Likert scale was employed to measure their perceptions. A general review of other related research papers revealed an empirical data oriented approach employed to estimate an indicator based SD index.

Amongst other things, energy use and efficiency is an important component of urban sustainability. Somashekar and Nagesha [9] have attempted to analyze the factors influencing the energy consuming behaviors and the nature of their influence in urban households of Mysuru, a south Indian city. Principal Component type Factor analysis was adopted to determine the significant variables which influence the adoption of energy efficient devices and conservation measures. They have also studied the adoption of energy efficient technologies in urban households [10].

GJ Satish and Nagesha [11] have analysed the pattern of energy consumption in the residential sector of Davanagere city in Karnataka State, India, and also estimated the environmental impact in terms of CO_2 emission. The energy efficiency level is computed in terms of Specific Energy Consumption (SEC) and Energy Intensity (EI). The factor analysis was carried out by Principal Component Analysis (PCA) method to find factors influencing energy efficiency and energy consumption. The authors compared the energy consumption pattern and environmental impact in the residential sector of two cities in another work [12].

In the context of an urban city, GJ Satish and Nagesha [13] have also identified the barriers which prevent implementation of energy efficiency standards, apart from studying drivers which promotes its adoption. The various barriers and drivers were identified for both residential and commercial sectors and subsequently ranked those using appropriate techniques.

III STUDY CITY AND METHODOLOGY

This research study was conducted in various households of different areas of Davanagere city, Karnataka, India. Davanagere, located in central part of Karnataka, is a corporate city with a population of about 5.20 Lakhs. It is spread over an area of about 77 square kilometers and is the seventh largest city in the state of Karnataka. With a literacy rate of about 85% and population growth of about 1.75% annually, Davanagere is experiencing all the sustainability challenges faced by modern cities.

Considering the potential opportunities and challenges, the city was selected as one of the hundred Indian cities to be developed as a smart city under "**Smart Cities Mission"** of Government of India. The city is witnessing a sea change in all fronts ever since the commencement of implementation of the Smart City Project. Therefore, the current study on indicator based sustainability index merits significant attention.

In view of the difficulty in studying an entire population, statistical sampling technique was employed in this research. A simple random sampling method was selected out of different sampling techniques to gather data pertaining to the major indicators to attain sustainability. The questions were specific related to different kinds of indicators to attain city sustainability. The dimensions for assessing these parameters were obtained from catalogues, journals and other available literature apart from discussion with experts in the field. The survey was based on a random sample of 40 houses in the city.

Data regarding indicators development and selection of important indicators for development of city sustainability index for this urban residential sector was obtained from the household participants with a well designed questionnaire. This researcher administered questionnaire was formulated on the basis of three pillars of sustainability, viz., Environmental, Social, and Economical dimensions of urban city. Questionnaire comprised inquiry based on the value judgment and perceptions of households on a five point Likert scale (anchored as 1 for non agreement; and 5 for strong agreement). Each of the three dimensions had same number of questions (20 each) to ensure an equal weightage for all the three dimensions of sustainability. Further, during researcher's personal visit to individual residences all the doubts were clarified regarding urban sustainability dimensions, thus eliminating any possibility of misconception.

Subsequently, weighted average index approach was employed for determining the index for all the indicators using the following formula.

$$WAI = \frac{\sum f_i w_i}{\sum f_i}$$

Where,

WAI is the Weighted Average Index;
f_i is the frequency of household respondents;
w_i is the weight of Likert scale score values.
(varies between 0.2 for 'Not agree' to 1.0 for 'strongly agree').

Finally, the Inter Quartile Range (IQR) method was used for identifying the major indicators. With these major indicators sustainability index for urban city was estimated.

IV RESULTS AND DISCUSSION

a. Development of sustainability index

As explained in the methodology researcher personally visited the households in the study area with set of questionnaires and collected the responses of respondents regarding urban sustainability. The perception based data was collected using a five point Likert scale. The questionnaires designed for the survey contained dimensions pertaining to three pillars of sustainability.

b. Indicators selection:

Indicators were selected based on different principles, a few of the principles adopted in this study are as follows:

- Indicators selection was directly related to urban city's environment, social, and economical elements.
- The data pertaining to indicators were available easily for assessment of sustainability.
- Cost involved in selection and measurement of indicators was reasonable.
- The indicators provided were very much significant in urban policy formulation and related services.

The survey used 60 indicators comprising 20 questions for each of the three sustainability pillars chosen. Afterwards, perceptive opinions for these indicators were obtained from the respondents during face to face interview of the researcher with the owner of the residences. After that, for identifying key indicators for urban sustainability, weighted average index and inter quartile range methods are used.

c. Calculations:

The formula for WAI employed the following weights from the Likert scale;

Not agree (1)	0.2
Slightly agree (2)	0.4
Moderately agree (3)	0.6
Agree (4)	0.8
Strongly agree (5)	1

Since there were a total of 40 respondents, the denominator was 40 in the WAI formula. An example of WAI calculation for the indicator "promotion of energy efficient Vehicle for less pollution", is shown below:

$$WAI = ((0\times0.2)+(0\times0.4)+(0\times0.6)+(19\times0.8)+(21\times1)) \div 40$$
$$WAI = 0.905 \text{ or } 90.5\%.$$

Similarly, WAI value was computed for all the sixty indicators. It was observed that out of 60 indicators used, half of the indicators had WAI score in the ranges of 50% to 100%. Hence, it indicated clearly that 30 indicators were very vital in attaining sustainability in this urban city.

d. Determining the key indicators:

After obtaining the WAI score for the 60 indicators, the next step was to find the key indicators for urban sustainability. For this purpose, a cut-off value or target point for selecting these indicators was essential. For fixing cut-off point several approaches were available. However, this study adopted the "Inter Quartile Range (IQR)" method. The IQR method, prescribes arranging all the indicators in the ascending order based on their WAI value. Subsequently, Lower quartile (Q_1), Middle quartile or Median (Q_2), and Upper quartile (Q_3) values were estimated. This study considered median (Q_2) as the cut-off point (the median Q_2 was at 79.5%). Then it was found that 30 indicators were above this cut-off point and hence all these 30 indicators were considered as key indicators for developing sustainability index

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e. Key indicator list

As per the selected cut-off point indicators were arranged in a table in the ascending order. Further, ranks were assigned to them based on their WAI value. Table 1 given below indicates the different Key indicators for each of the three pillars for achieving sustainability in the city.

Table 1: List of indicators with WAI value

PILLARS	INDICATORS	WAI in %	Rank
ENVIRONMENTAL	Promotion of energy efficient vehicle for less pollution	90.5	3
	Reinforcing girls' and women's rights	90	4
	Solar energy production	89.5	5
	Noise levels in selected residential areas	88.5	8
	Support local services and facilities	88.5	9
	Total amount of GHG emissions	88	10
	Loss of primary forest	88	11
	Percentage of water reused-recycled	86	16
	Changing our way of living	83	18
	Reducing water consumption.	81.5	21
	Emergency services	80.5	24
	Energy efficient building standards	79.5	28
	People should pay for the damage they cause to the environment.	79.5	29
SOCIAL	Gender equity	93.5	2
	Living space	87	12
	Crime rate	83	13
	Men and Women opportunities in income, education and employment.	86.5	14
	Improving people's health and opportunities for a good life.	84.5	17
	Save resources for future people.	82	19
	All the people must have access to good education. Everyone respect other cultures.	80.5	25
	Everyone respect other cultures.	80	26
ECONOMICAL	Develop a low emissions industrial zone	94	1
	Corruption makes imbalance in economic development	89.5	6
	Encourage residents to separate their garbage	89	7
	Reducing the environmental footprint of consumption through sharing network	86.5	15
	Importance in global networks	82	20
	Give poor free medical and dental care	81.5	22
	Economic growth as one of its highest priorities	81.5	23
	Control towards entry of Outside visitors	80	27

	Economic development is necessary for sustainable development	79.5	30

It may be observed that 11 indicators in environmental pillar, 10 indicators in social pillar and 9 indicators in economical pillar have emerged as vital in achieving sustainability index for an urban city.

f. Determining sustainability index:

Utilizing the above key indicators the value of sustainability index of the urban city was estimated. The calculation of Sustainable Development Index (SDI) was performed using the following equation:

$$\text{SDI} = \text{Likert scale score (ranges from 1 to 5)} \times \text{Number of respondents.}$$

Using above formula, SDI for each indicator under each of the three pillars was computed. It was found that SDI for environmental, social, and economical pillars was at 43, 38 and 40 respectively for the first residence. Then, assuming equal significance (one third) for all the three pillars of SD, overall SDI for the first residence was computed as follows:

$$\text{Overall SDI} = (1/3)\times(SI_{ENV}) + (1/3)\times(SI_{SOCI}) + (1/3)\times(SI_{ECON})$$

$$\text{Overall SDI} = (1/3) \times (43) + (1/3) \times (38) + (1/3) \times (40)$$

$$\text{Overall SDI} = 40.33 \quad \text{for first residence}$$

Likewise, the overall SDI was estimated for all the 40 residences in the city separately. Table 2 below provides the overall SDI values for the 40 residences selected in the study.

Table 2: Sustainable Development Index (SDI) Residences

RESIDENCE NUMBER	SUSTAINABILTY INDEX IN EACH PILLARS			OVERALL SDI
	ENVIRONMENTAL	SOCIAL	ECONOMICAL	
1	43	38	40	40.33
2	44	44	38	42
3	44	47	38	43
4	49	45	38	44
5	46	45	40	43.67
6	46	39	42	42.33
7	45	41	39	41.67
8	44	46	36	42
9	44	45	41	43.33
10	52	50	41	47.67
11	52	47	41	46.67
12	48	45	40	44.33
13	49	44	41	44.67
14	46	46	35	42.33
15	48	41	37	42
16	46	39	34	39.67
17	47	44	40	43.67
18	50	41	41	44
19	50	47	41	46
20	46	47	36	43

21	44	40	39	41
22	49	42	41	44
23	47	42	40	43
24	44	41	35	40
25	50	43	40	44.33
26	41	46	38	41.67
27	48	44	38	43.33
28	47	39	37	41
29	44	43	37	41.33
30	49	44	34	42.33
31	47	42	36	41.67
32	53	41	38	44
33	45	47	37	43
34	47	44	38	43
35	49	44	42	45
36	47	42	33	40.67
37	44	42	42	42.67
38	51	46	34	43.67
39	45	47	32	41.33
40	43	42	35	40
SUSTAINABILTY INDEX OF THE CITY				42.83

Finally, the SDI for the city is estimated by averaging the overall SDI obtained for the 40 residences selected in the study as follows:

SDI for the city = (Total of SDI for all the 40 residences ÷ Total number of residences)

SDI for the city = 1713.33÷ 40 = 42.83%

It is clear from the value of SDI for the city that significant scope exists for improving SDI in the city.

V CONCLUSION

The current paper was based on a research study conducted in the corporate city of Davanagere with the objective of estimating the Sustainability. Adopting an empirical approach with a scientific statistical sampling technique, the data pertaining to the three vital dimensions of SD was gathered using a structured researcher administered questionnaire. The data obtained was then analyzed using a weighted average method to arrive at the SDI.

The SDI obtained for the city was at 42.83% suggesting that there is significant scope for improving the sustainability of the city. In other words, a SDI of below 50% is an indicator of potential available to conserve energy, water and many other resources of nature to ensure a SD of this city in the long run. The results of this study have significant implications in the Planning and development of this corporate city in future.

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