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SUSTAINABLE AND SMART CITY PROJECT: AN OVERVIEW OF THE APPLICATION OF MULTIPLE CRITERIA DECISION MAKING TECHNIQUES AND APPROACHES FOR INDIAN CONTEXT

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Abstract - Sustainability assessment has become an important tool for planners and developers to aid in the shift towards sustainability and improving quality of life of humans. With the growing worldwide awareness on sustainable development, climate change and proper solid waste management facilities has become an important issue for country like India, smart city project is one such Project of Ministry of Urban Development for addressing such issues. Therefore, to achieve aim of Smart City Project to take advantage appropriate resources available and create a balanced and equal relationship between nature and human society, planners, developers and policy makers must take all the criteria need to analyze for it. This paper proposes an effective solution based TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) approach to help planners, developers and designer from different field like sociology, economics and engineering working for smart city project having a need to evaluate strategies and select states of India then further taking cities of these states for more deeper studies, considering the solid waste management and sustainable development as their main goal. The main objective of this paper is to combine and integrate solid waste generation, population growth, economic and social factor assessment procedures to support decision making in the context of smart city development in Indian Context (similarly can be applied to any part of world).

Keywords - Smart City Project, TOPSIS, Ministry of Urban Development, Solid Waste Management (SWM), Sustainable Development.

I. INTRODUCTION

Due to changing lifestyles and rapidly growing development across various part of world has led solid waste management (SWM) to become a global concern. In a developing country, solid waste management related problems are more critical than in a developed country (Zerbock 2003). In developing countries, most municipalities spend a large portion of their funds on the collection, transportation, and disposal of generated solid waste. In addition, metropolitan and urban industrial and domestic effluents are often released into waterways with little or no treatment (World Bank 2000). Waste management is considered mainly an issue related to technology and its development, which is often misguided approach as resulted in technological option that are not suitable in the given part of society, economy and environment.

The awareness regarding waste management and its related issues began in 1992 with the Rio Conference at the international level where waste was made one of the urgencies of Agenda 21 .In 2002; Johannesburg World Summit was focused on initiatives to accelerate the shift to sustainable production and consumption the reduction of waste. Though in India SWM was promoted by India Government as early as 1960's by giving loans for setting composting plants. Many Years after that we are still struggling for find the way to solve our problem of Solid Waste Management. Municipal Solid Waste (MSW) is nothing but useful material at wrong place if recycling factor is kept in mind. The industrial and commercial waste compositions remain relatively steady over the years whereas residential waste compositions are high in quantity and vary with season and time; these points are to be considered while planning under solid waste management for any nation.

It is a difficult concept to define sustainable development using mathematical terms. Experts, decision makers, planner and policy makers were proposed many methods such as ecological footprint, human development index and time series analysis to evaluate and measure sustainable development. Many sustainable development attributes can be considered using MCDM method which is the main advantage of these methods. Fundamentally, there are two techniques of weighting methods, subjective and objective weights one such method is fuzzy TOPSIS that can be used to evaluate sustainable development based on objective and subjective weights. The objective of this work is to develop TOPSIS method for selection of state in India which can perform better or can be planned better for smart city development specially taking solid waste management in mind. The ideal state among MP, Maharashtra, Gujarat, Kerala, Uttar Pradesh, Delhi and Tamil Nadu is recognized with a assumed alternative that has best figures/values for selected criteria of waste generation, population, GDP and literacy rate whereas the negative solution having worst criteria values. Idea behind taking TOPSIS methods for selection of state performance is due to following reason: -

- Simplicity of choosing any parameters among different parameters available of importance for planning/designing/Engineer
- Rationality,A sound logic that represents the
- rational of human choice
- Good computational efficiency for solution to be solved
- Ability to measure the relative performance in a simple mathematical form
  (easily programmed into a spreadsheet) for each alternative (7 states in our case of planning).
- Comprehensibility

The objective of this work is to investigate the application of TOPSIS (multi-criteria decision) making for sustainability evaluation for smart city project for seven states of India. To achieve these goals, we are addressing following question;
Which state performs better or have better prospects for smart city project for the criteria parameters?
How rating of these states changes with the varying weights of social, economic and technical parameters? How do the seven states of country differ in terms of social sustainability indicators?

The National Problem of Solid Waste Management and the Smart City Project

In the world, India is the second largest when population is considered (1.21 billion in figure, Parvathamma, 2014). Based on such a huge population, it does not have effective systems to treat its solid or organic wastes generated. Another reason is lack of enough resources for proper solid waste management (Parvathamma, 2014). Its urban population grew at an alarming rate of nearly 32 percent, during the last few years and it is facing a huge challenge to manage balance between its continuously increasing population and available resources. Solid waste management (SWM) is the most critical factor for the nation, which aims at smart city development. Improper management of solid waste effects public health quickens degradation of natural resources, causes climate change, leads to environment pollution, and hugely impacts the citizen's standard of life. The main reason for improper solid waste management are two-fold; one, some section of population do not get proper waste collection system and second, people don't segregate their waste in correct way. In India, the per capita rate of generation of waste has gone up from 0.44 kg per day in year 2001 to 0.5 kg per day in year 2011 (Mundhe, 2014). Smaller town's collection rate of waste is approximately about 50 to 55 percent, whereas for big cities it is about 70 to 90 percent (Manisha, 2014). Formally about 85-90 percent of the waste collected ends in either landfill or open low-lying lands (Parvathamma, 2014). To address the situation created due to mismatching of population growth rate and services offered, smart city development is project under Ministry of Urban Development. For promoting cities in India that providecore infrastructure and sustainable environment, Indian planners and policy makers have considered many critical factors as suggested by many researchers for smart city development are as follows: -

- Solid waste management and hygiene
- Good and easy accessible Public transport
- Inexpensive housing and sustainable environment, especially for the deprived class.
- Good Health and proper education.
- Regular and ample electricity supply

Under solid waste management projects like waste to energy, waste to fuel and compost, recycling plants, treatment of waste water plants are of most priority for sustainable infrastructure development. Country for smart city project is using the competition or challenge method to select cities amongst various states for funding and area based development.
For sustainable solid waste management system factor like urbanization migration of population from rural to urban areas), suburbanization, GDP per capita, Illiteracy / level of public awareness amongst citizens and Sanitary services are important and need constant attention for better planning (Hockett et al., 1995). The prediction and estimation of municipal solid waste generation rate play an important role for smart city development and factor above mentioned need to analyze for sustainable planning of cities under the project.

In this paper, we have selected 7 states like Madhya Pradesh, Maharashtra, Gujarat, Uttar Pradesh, Kerala, Tamil Nadu and Delhi for our study. Numbers of smart cities for development under project in this state are as follows: -

Table 1: Number of city in different states included for project

State	Number of cities
Uttar Pradesh	13
Tamil Nadu	12
Maharashtra	10
Madhya Pradesh	7
Gujarat	6
Kerala	1
Delhi	1

Source:http://smartcities.gov.in/content/innerpage/no-of-smart-cities-in-each-state.php

Among these following states, Uttar Pradesh has most number of smart cities for development under this smart city development project. For smart city development waste generation and proper treatment/ planning of it is most important criteria both in terms of sustainable development and climate change topic which is most priority for planner and developers across the world. In paper, we are attempting to find

out which state must improve certain parameters for proper solid waste management and which state has best prospect of better development under this project of smart city development introduced by the Government of India. Smart city project is dream project of Government of India considering both sustainable development and climate change. Policy makers, developers and planners are continuously monitoring parameters and constraints for infrastructure development to support the need and necessity of citizens for sustainable development. In this paper multi criteria decision making method has been used to select the best state among the seven states selected for the study. This study will help to analyze certain parameters on which solid waste generation depends like population growth or migration of people from rural to urban area which is also a concern globally, GDP growth or income growth and literacy level or level of awareness among citizens.

II. LITERATURE REVIEW

The European Smart Cities project, over the last few years has drawn the attention of many research scholars across different parts of world from various disciplines such as, for instance, economic sociology, economy of ICT, “marketing places” studies, communication studies, urban studies etc. Tremendous challenges are faced by communication experts, sociologists, planners, developers and research scholars who come across issues involving the quality of life, the environment and protest connected with integrated waste management policies.

In 1972, United Nations Conference on Environment and Human Settlements having agenda that there was a need for adequate provision of equitable and sustainable access to municipal services for healthy living (Mahadevia "Globalisation"). In India initiated by the Central Government in 2005, The Jawaharlal Nehru National Urban Renewal Mission (JNNURM) was to improve the urban services and infrastructure in 35 cities having one million plus population in 2001 (Census of India) and 28 other urban areas of historical/religious or tourist importance (JNNURM 8).

Multiple criteria decision making (MCDM) one of the most prevalent among for conflict management, the many such approaches available among which TOPSIS (technique for order preference by similarity to an ideal solution) and VIKOR methods are based on an aggregating function representing nearness to the ideal solution. Vector normalization is used in TOPSIS method to eradicate the units of principle functions and it determines a solution having minimum distance to the ideal and the maximum distance from the negative-ideal solution (Yoon and Hwang, 1981; Yoon, 1987). Multicriteria decision making (MCDM) may be considered as a dynamic and complex process including one engineering level and one managerial level (Opricovic, 1980). The managerial level in this method defines the goals, and chooses the ‘‘optimal’’ final alternative and the engineering level defines substitutions and points out the consequences of selecting any one of them. The TOPSIS method is very useful for solving of real problems by providing us with the alternative's ranking or the optimal solution. This method is not so complicated for the managers, planners and developers as some other methods used for selection which demands additional knowledge. The main step of multiple criteria decision making is shown in figure below: -

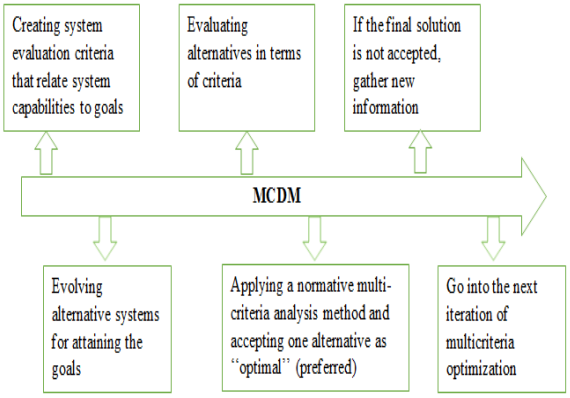

Fig.1. Main step of MCDM (Source: SerafimOpricovic 2002)

III. METHODOLOGY

The main goal of this work is to develop TOPSIS method for selecting state among seven states in India which can do better or had better prospect for smart city development. In this case, where real problem of solid waste management for planning/designing the smart city in these seven states are to be solved, the planner/developers often had to decide by choosing one out of many alternative solutions based on several decisions, this paper is one such attempt. Therefore, let us assume that we are given 7 – alternatives (Madhya Pradesh, Maharashtra, Gujarat, Uttar Pradesh, Kerala, Tamil Nadu and Delhi) and that 4-criteria (waste generation, population, GDP and literacy rate) is being assigned to each of them (as shown in figure below)

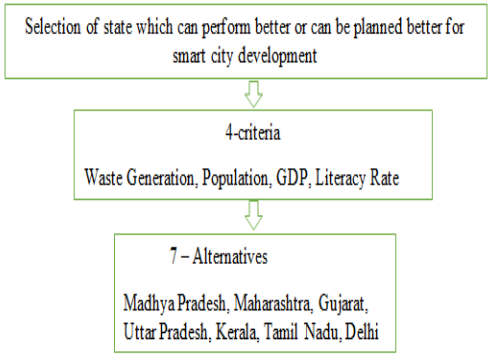

Fig.2. Selection criteria of TOPSIS

IV. TOPSIS METHOD

TOPSIS was first presented by Yoon (1980) for solving the problem having conflicting criteria. Researchers have applied TOPSIS to solve MCDM problems interrelated to different fields of studies like the government bond capitals valuation (Bilbao-Terol et al., 2014) and energy/power (Wang et al., 2014). The main principle of TOPSIS method is based on the concept that, the chosen (the best) alternative amongst all the alternatives, must be farthest from the Negative Ideal Solution (NIS) and the closest from the Positive Ideal Solution (PIS).

In this work, let there are x alternatives and y criteria for any decision-making problem, then, decision matrix is defined as $Dx = [g_{ij}]_{x\times y}$, where $i = 1, \dots\dots, x$ and $j = 1, \dots\dots y$. The TOPSIS procedure (Opricovic, 2002) is as follows:

1. Calculate the normalized decision matrix $Dx_{normalized} = [m_{ij}]_{x\times y}$; where $m_{ij} = g_{ij} \Big/ \sqrt{\sum_{i=1}^{x} g_{ij}^2}$ and weighted normalized decision matrix. The weighted normalized value $a_{ij} = b_j * m_{ij}$; where b_j is the weight of the criteria. (1)

2. Determine the ideal solution and negative ideal solution (NIS)

$$a_i^* = \left(\max_i(a_{ij}) \middle| j \in K\right), \left(\min_i(a_{ij}) \middle| j \in L\right) \quad (2)$$

$$a_i^- = \left(\min_i(a_{ij}) \middle| j \in L\right), \left(\max_i(a_{ij}) \middle| j \in K\right), \quad (3)$$

Where K is associated with the benefit criterion and L is associated with the cost criterion.

3. Calculate the separation measure of respectively alternative from ideal solution and NIS using n-dimensional Euclidean distance.

$$Z_i^* = \sqrt{\sum_{j=1}^{y}(a_{ij} - a_i^*)^2} \quad i = 1, \dots\dots, x \quad (4)$$

$$Z_i^- = \sqrt{\sum_{j=1}^{y}(a_{ij} - a_i^-)^2} \quad i = 1, \dots\dots, y \quad (5)$$

4. Calculate the relative closeness of alternative O_i to ideal solution of interest, which is given by

$$S_i^* = Z_i^- \Big/ (Z_i^- + Z_i^*) \quad (6)$$

5. Rank the alternative according to value of S_i^*. The alternative that has the maximum value of S_i^* among other alternatives is the best alternative. That alternative would have the minimum distance from the ideal solution and the maximum distance from the NIS.

Using the above method for our case study of 7 states (MP, Maharashtra, Gujarat, Tamil Nadu, Uttar Pradesh, Kerala, Delhi) giving more weightage to solid waste management as it is important for sustainable development and smart city project introduced by Ministry of Urban Development.

TOPSIS is used for selecting the best state; the preferable relative importance of each parameter is to be identified. Whereas in second case keeping solid waste generation weight constant and literacy rate more weight as higher literacy means more awareness regarding waste generation. Elements of the Decision matrix with different weights are shown in table below

Table 2: Elements of the Decision matrix

Alternatives	**Criteria**			
State	WG TPD	Population	GSDP in Crore	literacy
MP	4500	72597565	263396	70.63
Maharashtra	19204	112372972	1035086	82.91
Gujarat	7379	60383628	521519	79.31
Tamil Nadu	12504	72138958	584896	80.33
UP	11585	199581477	600164	69.72
Kerala	8338	33387677	263773	93.91
Delhi	7384	16753235	252753	86.34
Weight	0.35	0.25	0.2	0.2

Source: - Population Census 2011, CPCB (2000b, 2013).

Once the decision matrix is finalized from selection criteria, then it is normalize as these parameters are having different units. Taking equation (1), step 1 of method discussed above.

Table 3: Normalised values of Decision matrix

Alternatives	**Criteria**			
State	WG	Population	GSDP	literacy
MP	0.153618	0.2784471	0.17565	0.33024
Maharashtra	0.655575	0.4310052	0.69028	0.38766
Gujarat	0.2519	0.2316007	0.34779	0.37083
Tamil Nadu	0.426854	0.2766881	0.39005	0.37560
UP	0.395482	0.7654924	0.40024	0.32599
Kerala	0.284638	0.128058	0.17590	0.43909
Delhi	0.252071	0.0642568	0.16855	0.40370

After having a matrix of normalized values, we have to obtain the weighted values of decision matrix. Weighted values are calculated and shown below in table 4, for further calculation

Table 4: Weighted values of Decision matrix

Alternatives	Criteria			
State	WG	Population	GSDP	Literacy
MP	0.053766	0.069611	0.0351309	0.0660495
Maharashtra	0.229451	0.1077513	0.1380567	0.0775332
Gujarat	0.08816	0.0579001	0.0695587	0.0741666
Tamil Nadu	0.14939	0.069172	0.0780117	0.0751205
UP	0.138418	0.191373	0.0800481	0.0651986
Kerala	0.099623	0.0320145	0.0351812	0.0878198
Delhi	0.088224	0.016064	0.0337114	0.0807407

The Negative ideal solutions (NIS) and the Positive ideal solutions (PIS) are defined according to the weighted decision matrix via equations (2) and (3), step 2: -

Table 5: The ideal and non-ideal solution

PIS	NIS
0.053766	0.229451
0.016064	0.191373
0.138057	0.033711
0.08782	0.065199

Calculation of the separation measure of each seven alternative from ideal solution and NIS using n-dimensional Euclidean distance (taking equation (4) and (5), step 3) is shown below: -

Table 6: Separation distance of each competitive alternative from the ideal and non-ideal solution

State	Z+	Z-
MP	0.118047	0.219001147
Maharashtra	0.198438	0.351671075
Gujarat	0.088385	0.287388496
Tamil Nadu	0.12543	0.27488848
UP	0.204392	0.233716934
Kerala	0.113757	0.257568548
Delhi	0.110116	0.257333094

Computed the relative closeness of each location to the ideal solution by using equation (6) which shown below: -

Table 7: Computed the relative closeness of each location to the ideal solution

State	Closeness coefficient (Si)
MP	0.649762933
Maharashtra	0.63927558
Gujarat	0.764791832
Tamil Nadu	0.686674287
UP	0.533468067
Kerala	0.693646403
Delhi	0.700323967

Table 8: Computed the relative closeness of each location to the ideal solution for 2 case

State	Closeness coefficient (Si)
MP	0.64330876
Maharashtra	0.648777985
Gujarat	0.766386899
Tamil Nadu	0.688982378
UP	0.570340912
Kerala	0.688641885
Delhi	0.687897907

Similarly doing for changed weight for Waste generation, Population, GSPD and Literacy rate of 0.35, 0.2, 0.2 and 0.25 respectively and following the same procedure as above mentioned. Computed the relative closeness of each location to the ideal solution by using equation (6) which shown below: -

For the first case when weight of Waste Generation, Population, GSDP and Literacy rate was given weight 0.35, 0.25, 0.2 and 0.2 respectively, Gujarat suited the most because of it has higher values while Uttar Pradesh least suited having lower value as shown in table 7. This implies that if the planner/ design or policy maker has these four criteria and having these seven alternatives same priority as weight assigned then more efforts are required for Uttar Pradesh for smart city Project and least for Gujarat. Similarly, in second case where waste generation, population, GSDP and Literacy was weighted 0.35,0.2, 0.2 and 0.25 got same result but now Tamil Nadu performed better than Delhi which was previously better than Tamil Nadu in first case. Comparison of two cases is shown in Figure below: -

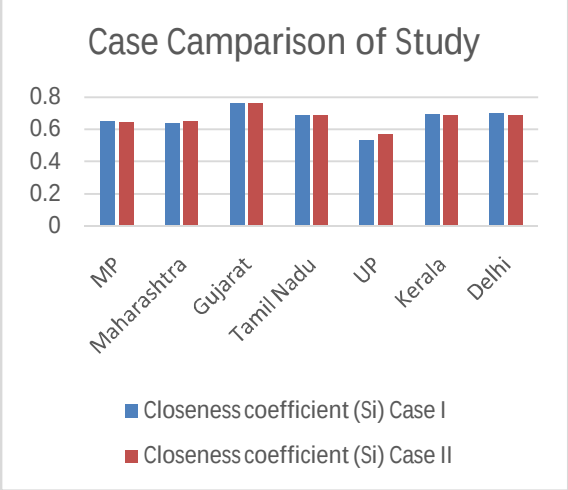

Fig.3. Closeness Coefficient for two different weighted cases

Similarly, Planner can vary any weight of criteria parameters or add for any number of state/ alternatives needed for smart city project planning/ development which is under progress in India.

CONCLUSION

The proposed new procedure for Planning selection is to find the best state in India suited most with least effort and most effort required state for smart city project of among available seven chosen state (more state can be taken) using of decision making method. After inspection the aggregations on several process constraints like waste generation, population, GSDP and literacy under different circumstances (with different weights), it is observed that the proposed model is expressive for aggregation and rather simple to use with the process parameters. TOPSIS is

applied to achieve final ranking preferences of states between seven selected state/ alternatives in descending order for solid waste generation as more weighted parameter/ criteria for this paper because of its national and international concern; thus, allowing relative performances to be compared.

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