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Multicriteria analysis of Swachchha Bharat Abhiyan based on public feedback: Search for best alternative using Cheng's Fuzzy techniques

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Abstract
In this project, an analysis of the public opinion is carried out by Fuzzy Multi-criteria Analysis. The study includes an small scale survey of a distributed population of India that aims to capture their opinion on alternatives that are available for an goa of Clean India. There are 9 criteria that includes Construction of community and individual toilets, elimination of open defecation areas, accountability and planning mechanism of monitoring toilet use, Public awareness programme to promote the use of latrines, Recruitment of a staunch ground staff to bring about a big behavioural change, Proper management of liquid and solid waste in villages, setting up network of water pipelines in rural areas, construction of toilets separately for girls and boys in all Indian schools, provision of the toilet facility to all Aanganwadis. These criteria were used to rate, analyse and finally rank based on the public rating. The study concluded the result in the form of the best alternative as a public response and a feedback output to the governing agencies. The rating of the alternatives will help the governing agencies or official private agencies for an efficient Swachchh Bharat Mission planning and implementation. Apart from the ranking analysis of the alternatives, a result comparison of the output by three methods named Cheng's Extent, Cheng's Entropy and Buckley's Fuzzy AHP is done. Results from these methods would help to remove any sort of biasness in selection of any alternative regarding the selected mission to provide fresh drinking water, to eliminate Open Defecation, Sanitation and Hygiene along with Solid Waste Management under Clean India Project.

Keywords: Rational Infrastructure Planning, Multicriteria Analysis, Fuzzy Logic, Swachchha Bharat Abhiyan, Cheng's Extent Method, Cheng's Entropy Method, Buckley's Method

1. Introduction
As per report released on World Water Day, India have most number of people without having access to clean drinking water. Almost 76 million which constitutes about 5% of our population does not get safe drinking water. People have to depend on lakes and ponds for the water requirement for their daily use which is not fit for drinking due to which diseases like Cholera, Jaundice occurs. Every year in India 2 million children under 5 year of age die due to poor health which is highest in the world. Diseases like diarrhoea, pneumonia are the major problems which occurs due to poor sanitation condition of India. This is not just the case of Indian villages, in our National capital also where 20% population lives in slums, the infant mortality rate is almost doubled in a year. Less than 50% of Indian households have excess to a toilet at home and in rural areas this condition is worse as only 32% of people residing in rural areas have excess to a toilet at home and tap water (NSSO 2012, Census 2011). In fact, Census 2011 reveals that in Rural India percentage of people having excess to personal television and phones is much more than a toilet facility at home. Out of 2.4 billion people globally which have lack of sanitation facilities, 1 billion defecates in open from which half of them are Indians. Lack of sanitation leads India to lose roughly 6.4% of its gross domestic product (GDP) which causes extra burden on government (World Bank 2017). Out of the 2907 sample urban blocks, 42% wards are lucky enough to be having community toilets for their use and 1.6% wards are not using community toilets on having the opportunity to use it from the whole India. Cleaning of provided community toilets is mainly done by local municipal bodies which consists of majority portion of urban areas 73.1% and some small potion about 12.2% is done by some Society Welfare Organizations where as 8.6% complained that the toilets are not at all cleaned by anyone.

When it comes to proper disposal management, 36.8% of the wards have it. 56.4% of wards have proper sewer system, 78.1% have water supply system to houses and street cleaning system and 64.2% wards also have solid waste management system and among them 48.2%, 37.7% and 9.3% of the solid waste dumps are cleaned on daily, weekly and monthly basis to ensure proper working mechanism of the solid waste management system. This condition worsens in our villages as in villages waste management is not at all there but the system of nali for letting waste out of there households is there in which 36.7% villages have pakki nali and 19% have kachhi nali and almost 44.4% have no arrangement of nali system also and when it comes to garbage disposal, most people almost 50.5% keep their household waste at a specific place outside their own houses, 24.4% people dispose of that in their own or nearby agricultural fields and a very few people 5.5% keep at a common place in the village or in a barren land, 4.4% use their garbage smartly like using it in Biogas plants or dumping it off by making manure pits and fraction of them i.e.15.1% throw around their own houses. This keeping of garbage at a common place or around houses is the major cause of health problems occurring in villages like Dengue, Malaria, and Diarrhoea etc. For the study a manual survey was conducted with a sample size of 50 distributed all across the country. The survey was to capture the people opinion toward the alternative for a combined goal of Clean India. The ratings for the alternatives were taken with respect to each criteria and each criteria is rated in a linguistic response. The response in the form of ratings was then converted to fuzzy scale comparison score with 0% inconsistency. All the alternatives given by our government for Clean India under Swachchha Bharat Mission will be evaluated on same scale so that the best among all the alternatives can be selected and implemented as soon as possible. A priority list of all the alternatives will be obtained so that the important among them can be preferred. Using a nationwide survey conducted based on preference of people on various alternatives, the project will help in the analysis of the status of Sanitation and Hygiene Conditions in India. Study will also result in analysing the behavioural pattern of people towards elimination of Open Defecation from whole country. Results can help us to suggest the best alternatives to achieve the target set by the Government of India for a Clean India and to provide opinion poll in the form of a feedback by conducting survey regarding Swachchh Bharat Abhiyan.

2. Methodology: Various Fuzzy AHP methods are applied to select the priority of various alternatives which are written below:

- Cheng's Entropy-Based Method (1996).
- Cheng's Extent Analysis Method (1992).
- Buckley's Method (1985).

For the study the following criteria are to be used to rate and compare best alternative for a common goal of Clean India. Indian government have already in an investment phase for the project, the study aims to efficiently capture feedback of people towards the policies in order for the decision makers to make accurate decisions for the project.

The criteria considered for Clean India project are

C1: Construction of community, cluster and individual toilets.

C2: To eliminate or lessen open defecation in rural areas. Open defecation among one of the prime reasons of behind the deaths of under 5 children every year.

C3: Apart from the construction of latrines, the Swachchh Bharat campaign also looks to establish an accountable and well-planned mechanism of monitoring their use.

C4: Public awareness programme to be provided to people in order to tell them about the drawbacks of defecating in open and to promote the use of latrines.

C5: Recruitment of a staunch ground staff to bring about a big behavioral change in people and promote the use of latrines at a micro-level.

C6: Proper management of liquid and solid waste in villages in order to keep them clean and disease-free.

C7: To setup a network of water pipelines in rural areas, ensuring a regular water supply to people by the year 2019.

C8: To construct toilets separately for girls and boys in all Indian schools.

C9: To provide the toilet facility to all Aanganwadis.

Above criteria will be used for evaluating ranking for the following alternatives that contributes towards the goal of Clean India:

A1: Free Individual Toilets by government.

A2: Free Common Community Toilets, Maintained by government.

A3: Paid Common Community Toilets, Maintained by Private Organization.

A4: Funding Private well developed sanitary organizations like Shulabh Suchalaya for hygiene throughout the country.

A5: Funding Educational sectors & Encouraging awareness among people encourage people for clean India.

A6: Investing in River Cleaning projects like Project Ganga.

A7: Partially subsidizing cost of toilet construction.

A8: Full investment in modernizing Municipal management organizations.

A9: Investment in Recycling and Environmental concerning NGO's for clean India.

2.1 Buckley's Fuzzy AHP

The fuzzy scale for the Buckley's Fuzzy AHP method for a given difference in rating value of any alternative or any criteria. A fuzzy trapezoidal function is taken for defining a fuzzy scale. The following table shows the fuzzy scale associated with the method:

Table 1: Fuzzy Rating Scale; Buckley's Fuzzy AHP

Difference (C_i-C_j)	Fuzzy Scale	Linguistic Scale (C_i)	Difference (C_i-C_j)	Fuzzy Scale
8	8,8.5,9,9	Extremely Important	-8	0.11,0.11,0.11,0.12
7	7,7.5,8,8.5	Highly Important	-7	0.11,0.12,0.13,0.14
6	6,6.5,7,7.5	Very Important	-6	0.13,0.14,0.15,0.16
5	5,5.5,6,6.5	Slightly More Imp.	-5	0.15,0.16,0.18,0.2
4	4,4.5,5,5.5	Weakly More Imp.	-4	0.18,0.2,0.22,0.25
3	3,3.5,4,4.5	Important	-3	0.22,0.25,0.28,0.66
2	2,2.5,3,3.5	Slightly Imp.	-2	0.28,0.66,0.4,0.5
1	1,1.5,2,2.5	Weakly Imp.	-1	0.4,0.5,0.66,1
0	1,1,1,1	Equally Imp.	0	1,1,1,1

Saaty's AHP method is further extended by Buckley to incorporate fuzzy comparison ratios a_{ij}. He found out that Van Laarhoven and Pedrycz's (1983) method has two problems.

First, a unique solution is not always possible for the obtained set of linear equations. Second, their weights are always insisted to be obtained on a triangular fuzzy number. Buckley's (1985) approach is shown in the following steps.

Step 1. Find out the Comparison Matrix C by consulting a Decision Maker in the form of trapezoidal fuzzy number.

Step 2. The fuzzy weight w_i will be calculated from the geometric mean for each row which will be determined as

$$\widetilde{z_i} = \prod_{j=1}^{n} \widetilde{t_{ij}},$$

and Fuzzy Weight

$$w_i = \widetilde{z_i} \oplus \left[\sum_{j=1}^{n} \widetilde{z_j}\right]^{-1}$$

$$w_i = \left(\frac{a_i}{d}, \frac{b_i}{c}, \frac{c_i}{b}, \frac{d_i}{a}\right), \forall\, i$$

Consider x to be the real number on horizontal axis, the membership function μ_{wi} (x) can be summarized as following:

Table 2: Membership Functions

	μ_{wi} (x)
$\leq a_i/d$	0
$\geq a_i/d$	0
$\left[\frac{b_i}{c}, \frac{c_i}{b}\right]$	1
$\left[\frac{a_i}{d}, \frac{b_i}{c}\right]$	α = [0,1]
$\left[\frac{c_i}{b}, \frac{d_i}{a}\right]$	α = [0,1]

Step 3. By aggregating the fuzzy weights and fuzzy performance scores, we can obtain fuzzy utilities U_i as

$$U_i = \sum_{j=1}^{n} w_j r_{ij}, \forall\, i.$$

Step 4. Finally, De-fuzzyfy the results using Centroid method.

$$\alpha = \frac{\int \mu_{u1}(X) * x\, dx}{\int \mu_{u1}(X) dx}$$

Calculate value of α from the obtained Utility equation and Rank the alternatives based on those values. Higher the value of α, Higher will be the chances to get selected.

Table 3: Difference value with Fuzzy Corresponding value

Difference (C_i-C_j)	Fuzzy Scale	Linguistic Scale (C_i)	Difference (C_i-C_j)	Fuzzy Scale
8	8,8.5,9,9	Extremely Important	-8	0.11,0.11,0.11,0.12
7	7,7.5,8,8.5	Highly Important	-7	0.11,0.12,0.13,0.14
6	6,6.5,7,7.5	Very Important	-6	0.13,0.14,0.15,0.16
5	5,5.5,6,6.5	Slightly More Imp.	-5	0.15,0.16,0.18,0.2
4	4,4.5,5,5.5	Weakly More Imp.	-4	0.18,0.2,0.22,0.25
3	3,3.5,4,4.5	Important	-3	0.22,0.25,0.28,0.66
2	2,2.5,3,3.5	Slightly Imp.	-2	0.28,0.66,0.4,0.5
1	1,1.5,2,2.5	Weakly Imp.	-1	0.4,0.5,0.66,1
0	1,1,1,1	Equally Imp.	0	1,1,1,1

$$a_1 = \left(\prod_{j=1}^{9} a_{1j}\right)^{1/9}$$

$$= (a_{11} * a_{12} * a_{13} * a_{14} * a_{15} * a_{16} * a_{17} * a_{18} * a_{19})$$

$$= (1 * 1 * 0.4 * 1 * 1 * 1 * 2 * 1 * 0.4)^{1/9} = 0.8810$$

$$Hence, a = \sum_{i=1}^{9} a_i$$

$$a = [0.8810 + 0.8810 + 1.3179 + 0.5015 + 0.5015 + 0.8810 + 0.3309 + 0.8810 + 1.3179 + 1.3179]$$

$$a = 7.4937$$

Similarly, we can get b_i and b, c_i and c & d_i and d which are written in the table below:

Thus, (a, b, c, d) = (7.4937, 9.4541, 10.7816, and 12.8958)

Now, the performance scores r_{j1}, j = 1 to 9 can be obtained as

$$r_{11} = \left(\frac{a_1}{d}, \frac{b_1}{c}, \frac{c_1}{b}, \frac{d_1}{a}\right)$$

$$= \left(\frac{0.8810}{12.8958}, \frac{1.0386}{10.7816}, \frac{1.2017}{9.4541}, \frac{1.4089}{7.4937}\right)$$

$$= (0.0683, 0.0963, 0.1271, 0.1880)$$

By Centroid Method,

$$\alpha = \frac{\int \mu_{u1}(X) * x\, dx}{\int \mu_{u1}(X) dx}$$

α = 0.1390

The Final Rankings

Alternate	α value	Rank
A1	0.1390	6
A2	0.1495	5
A3	0.1717	4
A4	0.0997	8
A5	0.1725	3
A6	0.0120	9
A7	0.1254	7
A8	0.1820	2
A9	0.1957	1

2.2 Chang's extent analysis method (1992)

The fuzzy scale for the Chang's extent method is defined for a given difference in rating value of any alternative or any criteria. A fuzzy triangular function is taken for defining a fuzzy scale. The following table shows the fuzzy scale associated with the method:

Cheng's Extent Method

Diff. (Ci-Cj)	L. Scale (Ci)	F. Scale	Diff. (Ci-Cj)	L. Scale (Cj)	F. Scale
8	Extremely Important	8,9,9	-8	Extremly Important	.11,11,12
7	Highly Important	7,8,9	-7	Highly Important	.11,12,14
6	Very Important	6,7,8	-6	Very Important	.12,14,16
5	Slightly More Imp.	5,6,7	-5	Slightly More Imp.	.14,16,20
4	Weakly More Imp.	4,5,6	-4	Weakly More Imp.	.16,20,25
3	Important	3,4,5	-3	Important	.20,25,33
2	Slightly Imp.	2,3,4	-2	Slightly Imp.	.25,33,50
1	Weakly Imp.	1,2,3	-1	Weakly Imp.	0.33,0.50,1
0	Equally Imp.	1,1,1	0	Equally Imp.	1,1,1

Let Objective Function as X= $\{x_1, x_2, \dots\dots, x_n\}$

And Goal Set as U= $\{u_1, u_2, \dots\dots, u_n\}$

While implementing, extent analysis method, m extent analysis values for each object are to be obtained as following:

$$M_{gi}^1, M_{gi}^2, \dots\dots, M_{gi}^m \; i = 1, 2, \dots\dots, n$$

Where all $M_{gi}^j \; (j = 1, 2, \dots\dots, m)$ are Triangular fuzzy numbers.

Consider triangular fuzzy comparison matrix expressed as:

$$\begin{pmatrix} M_{g1}^1 & M_{g1}^2 & \cdots & \cdots & M_{g1}^m \\ M_{g2}^1 & M_{g2}^2 & \cdots & \cdots & M_{g2}^m \\ \vdots & & & & \vdots \\ \vdots & & & & \vdots \\ M_{gn}^1 & \cdots & \cdots & \cdots & M_{gn}^m \end{pmatrix}$$

Step 1: The value for synthetic extent is given by $S_i = \sum_{j=1}^{m} M_{gi}^j \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^j\right]^{-1}$

Step 2: The degree of possibility of $M_{2,} = (l_{2,} m_{2,}, u_{2,}) \geq M_1 = (l_{1,} m_{1,} u_{1,})$ is given by $V(M_2 \geq M_1) = sup_{y \geq x}[min(\mu_{M1}(x), \mu_{M2}(y))]$

Step 3: Now, next step is to find degree of possibility of a convex number which should be higher than k convex fuzzy numbers $M_i = (i = (1,2,k))$ which can be defined as:

$$V(M \geq M_1, M_2, \dots, M_k) = V(M \geq M_1) and (M \geq M_2) and \dots . and \; (M \geq M_1)$$

Step 4: Using normalization method, the normalized weight vectors are

$$W = (d(A_1), d(A_2), \dots, d(A_n))^T$$

Where W is non-fuzzy number.

Final Alternative Ranking

Cheng's Extent Method

	Scores	Ranking
A1	0.12	5
A2	0.13	4
A3	0.14	3
A4	0.04	9
A5	0.12	6
A6	0.09	7
A7	0.07	8
A8	0.17	1
A9	0.15	2

2.3 Cheng's Entropy Method

The following method describes the Cheng's entropy method of multi-criteria decision analysis. The fuzzy scale for the Chang's entropy method is defined for a given difference in rating value of any alternative or any criteria. A fuzzy triangular function is taken for defining a fuzzy scale. Shannon entropy, H, which is applicable only to probability measures, assumes the following form in evidence theory (Klir and Yan, 1995):

$$H(m) = -\sum_{j=1}^{n} m(\{x\}) log_2 m(\{x\})$$

This function, which forms the basis of classic information theory, measures the average uncertainty associated with the prediction of outcomes in a random experiment. Its range is $[0, log_2|X|]$.

Clearly, H(m) = 0.

When m({x}) = 1 for some x∈ X; $H(m) = log_2|X|$, when m defines the uniform probabilities distribution on X(i.e, (m{x}) = 1/|X|, $\forall x \in X$).

The principle of maximum uncertainty is well developed and broadly utilized within classic information theory, where it is called the principle of maximum entropy.

Cheng's [1996] evaluation model can be described as given below:

Step 1: Construct a hierarchy structure for any problem.

Step 2: Build membership function of judgment criteria.

Step 3: Compute the performance score.

Step 4: Utilize fuzzy AHP method and entropy concepts to calculate aggregate weights.

The computational procedure of this decision-making methodology is summarized as follows.

To compare the performance scores, we can use symmetric triangular fuzzy numbers$\tilde{1}, \tilde{3}, \tilde{5}, \tilde{7}, \tilde{9}$ to indicate the relative strength of the elements in the hierarchy matrix.

To assemble the total fuzzy judgement matrix $\tilde{A}$, we can multiply the fuzzy subjective weight vector W~ with the corresponding column of fuzzy judgement matrix $\tilde{X}$. Thus, we get

$$\tilde{A} = \begin{bmatrix} \tilde{w}_1 \otimes \tilde{x}_{11} & \tilde{w}_2 \otimes \tilde{x}_{12} & \dots & \tilde{w}_n \otimes \tilde{x}_{1n} \\ \tilde{w}_1 \otimes \tilde{x}_{21} & \tilde{w}_2 \otimes \tilde{x}_{22} & \dots & \tilde{w}_n \otimes \tilde{x}_{22} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{w}_1 \otimes \tilde{x}_{n1} & \tilde{w}_2 \otimes \tilde{x}_{n2} & \dots & \tilde{w}_n \otimes \tilde{x}_{nn} \end{bmatrix}$$

$$\tilde{A} = \begin{bmatrix} \tilde{w}_1 \otimes \tilde{x}_{11} & \dots & \tilde{w}_n \otimes \tilde{x}_{1n} \\ \dots & \dots & \dots \\ \tilde{w}_1 \otimes \tilde{x}_{n1} & \dots & \tilde{w}_n \otimes \tilde{x}_{nn} \end{bmatrix}$$

Now fuzzy number multiplications and additions using the interval arithmetic and α cuts are made, and Eq. (30) is obtained.

$$\tilde{A}_\alpha = \begin{bmatrix} [a^\alpha_{11l}, a^\alpha_{11n}] & \dots & [a^\alpha_{1nl}, a^\alpha_{1nu}] \\ \vdots & \ddots & \vdots \\ [a^\alpha_{n1l}, a^\alpha_{n1u}] & \dots & [a^\alpha_{nn1}, a^\alpha_{nnu}] \end{bmatrix}$$

Where $a^\alpha_{ijl} = w^\alpha_{il} x^\alpha_{ijl}, a^\alpha_{iju} = w^\alpha_{iu} x^\alpha_{iju}, for\ 0 < \alpha \leq 1$ and all i, j.

Now the degree of satisfaction of the judgment Â will be estimated. When α is fixed, we will set the index of optimism λ by the degree of the optimism of a decision maker. A larger λ indicates a higher degree of optimism. The index of optimism is a linear convex combination it is explained by

$$\hat{a}^\alpha_{ij} = (1-\lambda) a^\alpha_{ijl} + \lambda a^\alpha_{ijl}, \forall\ \lambda \in [0,1].$$

Thus we have,

$$\hat{A} = \begin{bmatrix} \hat{a}^\alpha_{11} & \hat{a}^\alpha_{12} & \cdots & \hat{a}^\alpha_{1n} \\ \hat{a}^\alpha_{21} & \hat{a}^\alpha_{22} & \cdots & \\ \vdots & \vdots & \ddots & \vdots \\ \hat{a}^\alpha_{n1} & \hat{a}^\alpha_{n2} & \cdots & \hat{a}^\alpha_{nn} \end{bmatrix}$$

Where $\hat{A}$ is a precise judgment matrix.

$$H_1 = -\sum_{j=1}^{n} (f_{1j}) log_2 (f_{1j})$$

Where H_i is i^{th} entropy value.

The entropy weights can be determined by using Eq.

$H = \frac{H_i}{\sum_{j=1}^{n} H_j}$, i= 1,2……n

Entropy weightage and Alternative rankings

Entropy	Entropy weight	Ranking
-2.990	0.110	8
-2.984	0.109	9
-3.037	0.111	5
-3.063	0.112	2
-3.073	0.113	1
-3.057	0.112	3
-3.048	0.112	4
-3.005	0.110	7
-3.006	0.110	6
-27.264	1	

3. Results & Discussions: The study concluded with following rankings for the 9 alternatives judged based on 9 criteria. The conclusion on the basis of method used varies by a large margin. Although the results from Buckley's Fuzzy AHP and Cheng's extent method agrees with each other to a high degree, whereas Cheng's entropy method rankings deviates from the before two. This can be explained by the less dependency of criteria weightages on the fuzzy ratings taken for the study. The weightages for the Cheng's entropy method needed to be taken beforehand by the decision makers. The weightages for criteria were calculated by AHP process without incorporating the fuzzy scale decided for the study.

Alternative rankings as per various methods used

Alternate	Buckley's Fuzzy	Cheng's Extent	Cheng's Entropy
A1	6	5	8
A2	5	4	9
A3	4	3	5
A4	8	9	2
A5	3	6	1
A6	9	7	3
A7	7	8	4
A8	2	1	7
A9	1	2	6

Following are the further conclusions commenting on the numerical values of the weightages obtained for the alternatives:

- Fuzzy Entropy method resulted in almost equal weightages, with minimum variations.
- Cheng's extent & Buckley's Fuzzy AHP have similar Ranking pattern, while Cheng's Entropy ranking is deviated from other two.
- Range of variation in Weightages was highest in Buckley's Method.

Considering the ranks from three methods, Alternative A8 and A9 are ranked important for the Objective.

A8: Full investment in modernizing Municipal management organizations.

A9: Investment in Recycling and Environmental concerning NGO's for clean India.

The results shows an immediate behaviour of the people toward the choice of alternatives presented for the goal of Clean India. The ratings for the Municipal waste management and NGO's shows the short term mind set of the people toward the problem of waste management in the country. The alternatives gives fast but temporary solution

for the problem, these alternatives does not promise long term goal fulfilment.

Although the people opinion is found out to be non-rational and short term, the governing agencies should consider their mind set for a rational planning that might include provisions for a behavioural change in the people for a long term benefit approach.

4. Conclusion

In this project the importance of certain Criteria with respect to certain Alternatives is checked out with different methods and Alternatives are ranked as per their obtained priority to achieve best possible solution for Swachchha Bharat Mission. The behaviour of the people of the country toward Clean India is captured in the study in the form of priorities assigned by them to each available alternative for the project. The future scope of the project is that the several decisions made by the government bodies can be made more accurately by the decision makers with the help of various Fuzzy AHP methods and scope of any biasness can be completely removed. This study demonstrates a small but very structured survey and feedback system that is capable of handling large population for better results.

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