A Comparative Analysis of Multi-Criteria Decision Making Techniques for Ranking of Attributes for e-Governance in India

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***Abstract*—e-Governance is the system in which all the public services are made available in the online platform with the help of secured cyber architecture. Government along with the people have praised the ability of Information and communications technology (ICT) around the world in stimulating the various vital sectors of the economy. The advanced technologies have provided speed, inexpensive and convenient method of interaction and communication. In various developing and developed countries, these newly adopted technologies have shown direct positive impact on the country's productivity, efficiency and thus leads to rapid development. This work represents a comparative study of various Multi-Criteria Decision Making (MCDM) techniques like Technology, Multi-criteria Decision making, Ranking, Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Weighted Sum Model (WSM) and Weighted Product Model (WPM) to find the ranking of various attributes responsible for better decision making for implementing successful e-Governance in developing country, India.**

Keywords*—*e-Governance; information and communication technology; multi-criteria decision making; ranking; technique for order of preference by similarity to ideal solution (TOPSIS); usability; weighted sum model (WSM); weighted product model (WPM)

I. INTRODUCTION

The word e-Government refers to a broad set of applications defined and created in order to solve various administrative issues, i.e Government services or government sector-related issues. The development in utilize of Information Technologies and Communication Technology (ICT) has extended to new domains starting from entertainment and information sharing, to medicine, education and science [14]. Most of the e-Governance services are web-based applications. This helps the citizens for better access to the various e-Governance services [8]. e-Governance in India has advanced persistently beginning from digitization of government offices and departments to segregated sectors centered at adapting e-Governance usages in different areas of the government at various levels i.e. national, district, state or local levels. These segregated sectors were unified into a single vision and strategy given by the National e-Governance Plan (NeGP) in 2006 [3]. The NeGP takes a holistic scenario of e-Governance plans, strategy and activities within the nation, merging them into a cumulative and collective view for a common shared cause. Revolving around this digitization concept, a huge nation-wide infrastructure is evolving and made accessible to the people of the remotest of villages, and expansive scale digitization of records is been undertaken to have easy, secured and reliable access over the Internet services. e-Governance plays a major component of the country's governance system and also is a vital part of the administrative reform agenda in developing country like India. The NeGP organization has the capability to accumulate large savings in costs by the method of sharing of core and support infrastructure, empowering interoperability through measures, and of presenting a seamless view of government to citizens. The ultimate objective is to allow transparent public services to citizens.

In the course of time various strategies are planned and are implemented for designing better e-Governance for the citizens. But despite of so many proposals, some fail because of the improper implementation attributes. In order to make a project successful, it is required to study all the critical factors starting from governance, management to implementation and getting feedback on services responsible for making a successful project.

Multi-criteria Decision making techniques (MCDM) are useful in cases where many factors stands validated for the success of one cause. The conflicting areas are analyzed effectively in this process of decision making. In a typical MCDM algorithm, weights are assigned to each criteria available for analysis, and basing on the weights, each criteria is analyzed with reference to some collected data or information. Basing on the algorithm, the criteria are ranked or weighted in order of their dependency for the success of a given solution. The method of structuring difficult problems properly and focusing on multiple attributes explicitly proceeds to more informed and good decisions. A number of approaches and techniques have been proposed and applied in different fields for better decision making considering various attributes of a problem [11, 12].

Therefore, in this paper various models of decision making are analysed in order to find the preference order of attribute ranking for making better decision for successful and proper implementation of e-Governance in India.

II. Literature Review

There are various authors who have used the methods such as TOPSIS, WPM and WSM for ranking various attributes in order provide efficiency in the system. Some of the noted works of the authors are cited below.

Mela et.al (2012) have selected various MCDM techniques like WSM, WPM, VIKOR, TOPSIS, PROMETHEE II for a comparative study for building design. They have tested against various criteria that are responsible for generating better designs [1].

Velasquez et.al (2013) have reviewed various MCDM techniques for better performance attributes. The authors have concluded that, MCDM techniques provides a whole new approach for better decision making for any problem which combines multi-criteria attributes for evaluation[2].

Mulliner et. al (2015) have compared the performance of methods like WPM, WSM, AHP, TOPSIS and COPRAS for assessment of sustainable housing affordability. The authors have evaluated 20 criteria and 10 alternatives taking Liverpool as a case study. The reason for using the MCDM techniques is to evaluate the robustness and contrasts in the result rankings [4].

Karande et.al (2016) compared the most popular six comprehensive MCDM methods such as WSM, WPM, MOORA, MULTIMOORA and WASPAS for industrial robot selection problems using two real time values. Local weights were under-taken and stability were maintained by designing proper interval ranges. MOORA have given robust and best values for the most critical criteria [5].

Kolios et.al (2016) have used the TOPSIS method from MCDM techniques in order to provide enrichment for accounting stochastic variable inputs. Along with TOPSIS, PROMETHEE is also used for predicting the optimum design alternative [6].

Ansar et.al (2018) have used various MCDM methods like WPM, WSM, AHP, TOPSIS, SMART on 10 alternatives and criteria in order to evaluate the success of information system selection. Among the MCDM techniques, TOPSIS resulted in better and sophisticated values for ranking the alternatives in their order for efficient information system selection [7].

Mondal et.al (2021) have implemented the MCDM techniques for evaluation of factors and attributes responsible for smart city governance. The author has used Agartala city for the case study. The work is focused the various applications under taken for Smart cities. Both qualitative and quantitative analysis has been implemented. After evaluation of the criteria and its attributes, the author concludes that it would take 5 years of time for completion of project for making Agartala a smart city [9].

Chakraborty et.al (2021) have applied Decision making trial and evaluation laboratory (DEMATEL) method for their work. They have taken the case studies of 98 Indian smart cities for evaluation against 11 criteria. The proposed work also include k-means clustering algorithm for reduction of datasets. Finally, after the application of MCDM techniques, they have found out the results along with strengths and weakness relating to the progress of smart cities and measures for strengthening the lagging infrastructure for Smart cities [10].

III. Methodology

Multi-Criteria Decision Making techniques are used by decision makers for evaluating the conflicting criteria present as alternatives for taking proper and wise decision regarding a problem statement. Solving a particular problem has various options [12]. It may be finding the best alternative of the given set of alternatives, or ranking the alternatives to find the most critical factor for a given problem domain, or finding the deviation of the alternatives from a given set of most accurate alternatives or may be outranking the relations among the alternatives or may be deciding the criteria weights for each alternatives such that the best optimal solution are found from the given set of alternatives. A MCDM technique not only finds the best alternatives, it also provides a set of weak criteria or non-critical alternatives so that filtration can be made among the alternatives and would be helpful for the decision makers to take the best solution for the problem statement. Techniques like Aggregated Indices Randomization Method (AIRM), Analytical hierarchy Process (AHP), Analytical Network Process (ANP) are used for finding the weighted criteria for each alternative for finding the best solution to the given problem. Best Worst Method (BWM) is another technique used for finding the worst possibilities so that worst factors can be eliminated and best decision can be taken by the experts for decision-making. Some methods like ELECTRE and PEOMETHEE are used for outranking the alternatives and finding the most critical factors for decision-making in various fields. Techniques like Weighted Sum Model (WSM) and Weighted product Model (WPM) are used for finding the weights on each criterion for helping in decision making procedure. PAPRIKA is a technique to find the pairwise ranking among all possible alternatives available to find optimum solution. Ranking techniques such as Superiority and inferiority ranking method (SIR Method) , Technique for the Order of Prioritization by Similarity to Ideal Solution (TOPSIS) and Evaluation based on Distance from Average Solution (EDAS) are used for finding the differences among the similarity indices, or superiority and inferiority of alternatives for helping decision makers as most alternatives gets filtrated and best alternatives are outshined. Many MCDM techniques are available and each technique has some unique features for various problems. Techniques are applied looking into the problem statement defined and the results as desired by the researchers. In this research some MCDM Techniques like WSM, WPM and TOPSIS are used on the same set of criteria for evaluation of success of e-Governance Services in Indian Government. The techniques are compared and best fit technique is taken into account for the evaluation process.

A. Weighted Sum Model (WSM)

The importance of this technique is to simple add weights to each alternatives in the criteria for better assessment results [16]. The weights are evaluated using the following equation:

$$A_i^{\text{WSM- value}} = \sum w_j a_{ij} \text{ for } i= 1,2,3,\ldots., n \text{ and } j= 1 \text{ to } n \quad (1)$$

This technique is helpful for ranking of alternatives for better decision making.

B. Weighted Product Model

The method is called dimensionless analysis as the mathematical components eliminate the units of measurement. It was first experimented by Bridgman and Miller and Starr in 1922 [15]. The equation is stated as follows:

$P(A_K) = \prod (a_{Kj})^{w}_{j}$ for K=1,2,3…m. and j=1,2,3….,n. (2)

This method can also be used for comparison between two alternatives as per the following equation:

$P(A_K/ A_L) = \prod (a_{Kj}\, a_{Lj})^{w}_{j}$ for K, L=1,2,3…m. and j=1,2,3….,n (3)

C. Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)

In the TOPSIS method, the objective is to choose the alternative by measuring the shortest geometric distance from the positive ideal solution (PIS) and the longest geometric distance from the negative ideal solution (NIS). The technique was developed by Ching-Lai Hwang and Yoon in 1981 [13]. In this technique of decision making, a set of alternatives are compared by identifying weights for each criterion, normalizing the scores for each criterion and finally calculating the distance from the most ideal alternative available.

Steps for TOPSIS Method:

1) Creating the evaluation matrix having n-criteria and m-alternatives, with the intersection of each alternative to the given criteria denoted as x_{ij} of size (n x m).

2) Next step is to normalize the matrix values to form a Normalized matrix (R).

$R= (r_{ij})_{n\,x\,m}$ by the method.

$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{k=1}^{m} x_{ij}^2}}$, i= 1,2,3,……,m ; j=1,2,3,…,n. (4)

3) Next step is to calculate the weighted normalized decision matrix.

$t_{ij} = r_{ij}$ x w_j ; i=1,2,….,m and j= 1,2,…., n. (5)

$w_j = \frac{w_j}{\sum_{k=1}^{n} w_k}$, j=1,2,…., n so that $\sum_{i=1}^{n} w_i = 1$, and W_j is the original weight given to the indicator (6)

4) Finally, the worst alternative (A_w) and the best alternative (A_b) were determined.

$A_w = \{[\max (t_{ij} | i=1,2,3,….,m) \mid j \in J_-]\}, [\min(t_{ij} | i=1,2,3,….,m) \mid j \in J_+\} = \{t_{wj} \mid j=1,2,3,….,n)\}$ (7)

$A_b = \{[\min (t_{ij} | i=1,2,3,….,m) \mid j \in J_-]\}, [\min(t_{ij} | i=1,2,3,….,m) \mid j \in J_+\} = \{ t_{bj} \mid j=1,2,3,….,n)\}$ (8)

$J_+ = \{j=1,2,…,n|j\}$ (9)

having positive impact value on the criteria and

$= \{j=1,2,…,n|j\}$ (10) having positive impact value on the criteria.

5) The distances between the chosen alternative i and the worst chosen alternative is calculated by

$d_{iw} = \sqrt{\sum_{j=1}^{n} (t_{ij} - t_{wj})^2}$ i=1,2,3,…,m. (11)

the distance between the alternative i and best chosen condition is calculated by.

$d_{ib} = \sqrt{\sum_{j=1}^{n} (t_{ij} - t_{bj})^2}$ i=1,2,3,…,m. (12)

Similarity to worst condition is calculated by:

$s_{iw} = d_{iw} / (d_{iw} + d_{ib})$, $0 <= s_{iw} <= 1$; i-1,2,3,…,n (13)

s_{iw} =1 iff alternative is the best condition,

s_{iw} =0 iff alternative is the worst condition.

The alternatives are ranked according to s_{iw} (i=1,2,3….m).

There are various criteria for evaluation of e-Governance projects at national, state, district and zonal level. The criteria are broadly classified as Governance, Management, Resources and Promotion.

Each broad criteria is again categorized into various sub-criteria such as follows:

Governance is sub categorized into ministerial and parliament. Management is divided into Administrative and opportunities. Resources are grouped into technical and non-technical and finally promotion is segregated as social media and advertisement.

Each sub-criteria is again divided into various alternatives as described below:

Ministerial covers policy maker, strategy planner, legal framework and stakeholders as its alternatives. Similarly, Parliament has political willingness, information sharing, scope and collaborations as its alternatives. Administrative encompasses administrative policies, administrative strategies, evaluation and financial budget as its alternatives for ranking of attributes. Opportunities has user friendly, design and navigation, leadership and economy as its alternative attributes. Technical criteria has ICT infrastructure, software development, security and privacy as its alternatives. Non-technical covers support staff, awareness, disaster recovery and helpdesk as the alternatives. Social media has Facebook, twitter, WhatsApp and Google share as its alternatives. Lastly, advertisement covers television, print media hoardings and airshows as its alternatives.

The division of criteria, sub-criteria and alternatives are designed in order to bring clarity in the valuation process and also it helps for better decision making as the attributes are collected take all- round aspects of e-Governance system in a developing country like India.

Questionnaire and feedback mechanism were taken into consideration to put the numeric values against each attribute and criteria for ranking of the attributes for good governance system in India.

Each criteria is evaluated in three different methods using TOPSIS, WPM and WSM. And ranking of attributes are made

depending on the importance of attributes for providing good governance system to the citizens through cyber space.

IV. Results and Comparison

Information and data were collected from various experts in the e-Governance sectors through questionnaire in various national, state and district level governance management systems. Along with this, feedback were also included that were collected from various existing e-Governance projects for making them successful at different levels of operation.

The methods like WSM, WPM and TOPSIS were used to analyse the responses obtained from the questionnaire and the feedback system. The responses were in both numeric grading and linguistic order. All the linguistic values were converted into numeric ranking in terms of percentage values and were mapped against each attributes. Finally the methods of WSM, WPM and TOPSIS were applied and the ranking of attributes from most preferable to least preferable are ranked in terms of 1, 2, 3 and 4.

The results are compared for each attribute in the following tables:

From Table I, it is noted that Strategy planner is given more priority as per TOPSIS method, WPM Method and WSM Method.

TABLE I. Ranking of Alternatives for Ministerial Sub-Criteria

Sl No	Attributes	WSM	WPM	TOPSIS
1	Policy Maker	2	3	2
2	Legal Framework	3	2	3
3	Strategy Planner	1	1	1
4	Stakeholders	4	4	4

From Table II, scope has been given highest priority on analyzing in all the three methods.

TABLE II. Ranking of Alternatives for Parliament Sub-Criteria

Sl No	Attributes	WSM	WPM	TOPSIS
1	Political Willingness	4	2	4
2	Information sharing	3	3	2
3	Scope	1	1	1
4	Collaborations	2	4	3

The results in Table III, assigns highest priority to Evaluation in WPM and WSM method and Administrative policies in TOPSIS Method.

TABLE III. Ranking of Alternatives for Administrative Sub-Criteria

Sl No	Attributes	WSM	WPM	TOPSIS
1	Administrative policies	4	2	2
2	Administrative policies	2	3	1
3	Evaluation	1	1	3
4	Financial Budget	3	4	4

TABLE IV. Ranking of Alternatives for Opportunities Sub-Criteria

Sl No	Attributes	WSM	WPM	TOPSIS
1	User friendly	4	2	2
2	Leadership	2	3	1
3	Design and Navigation	1	1	3
4	Economy	3	4	4

From the Table IV, of Opportunities sub-criteria, TOPSIS ranks Leadership as most priority and WSM and WPM ranks Design and Navigation as the most preferred attribute.

As per Table V, ICT Infrastructure and software development are the most important attributes for governance system from the technical point of view.

TABLE V. Ranking of Alternatives for Technical Sub-Criteria

Sl No	Attributes	WSM	WPM	TOPSIS
1	ICT Infrastructure	1	2	1
2	Software Development	2	1	2
3	Security & Privacy	4	3	4
4	Accuracy	3	4	3

In Table VI, Awareness and Disaster recovery of the ICT systems are most important and hence are given highest priority.

TABLE VI. Ranking of Alternatives for Non-Technical Sub-Criteria

Sl No	Attributes	WSM	WPM	TOPSIS
1	Awareness	1	2	2
2	Disaster Recovery	2	1	1
3	Support staff	4	4	3
4	Help Desk	3	3	4

The importance of good governance system can be shared and spread through social media. Therefore, Facebook, Twitter are mostly used for sharing the information in promotion of e-Governance systems in Table VII.

TABLE VII. Ranking of Alternatives for Social Media Sub-Criteria

Sl No	Attributes	WSM	WPM	TOPSIS
1	Face book	2	1	2
2	Twitter	1	4	1
3	WhatsApp	4	2	3
4	Google share	3	3	4

Television and print media are popularly used for advertising various e-Governance systems for its promotion as per the results shown in Table VIII.

Similarly the ranking order of all the criteria are done using WPM, WSM and TOPSIS Methodology.

TABLE VIII. RANKING OF ALTERNATIVES FOR ADVERTISEMENT SUB-CRITERIA

Sl No	Attributes	WSM	WPM	TOPSIS
1	Television	2	1	2
2	Print Media	1	4	1
3	Hoardings	4	2	3
4	Air Shows	3	3	4

TABLE IX. RANKING OF SUB-CRITERIA

Sl No	Attributes	WSM	WPM	TOPSIS
1	Ministerial	6	5	4
2	Parliament	5	6	5
3	Administrative	4	1	1
4	Opportunities	1	2	3
5	Technical	2	3	2
6	Non-Technical	3	4	6
7	Social Media	7	7	7
8	Advertisement	8	8	8

From the Table IX, the priority ranking of various sub-criteria are as follows:

Using WSM, the ranking order are Opportunities> Technical> Non-Technical> Administrative> Parliament> Ministerial> Social Media> Advertisement.

Using WPM, The ranking orders are Administrative> Opportunities> Technical> Non-Technical> Ministerial> Parliament> Social Media> Advertisement.

Using TOPSIS, the ranking order are Administrative>Technical>Opportunities> Ministerial>Parliament> Non-Technical>Social Media> Advertisement.

The final ranking of criteria that are responsible for success of e-Governance system is shown in Table X.

TABLE X. RANKING OF CRITERIA

Sl No	Attributes	WSM	WPM	TOPSIS
1	Governance	2	1	1
2	Management	1	2	3
3	Resources	3	3	2
4	Promotion	4	4	4

The overall ranking of criteria are as follows:

In WSM method, Management> Governance> Resources> Promotion.

In WPM method, Governance> Management> Resources> Promotion.

In TOPSIS method, Governance> Resources> Management> Promotion.

The various criteria, sub-criteria and alternatives are compared and ranked according to their priority such that multi-criteria analysis can be done for better decision making for success of e-Governance in India.

V. CONCLUSION AND FUTURE WORK

The implementation of e-Governance in a developing country like India is very challenging in nature. The factors such as secured cyber space, advanced ICT infrastructure, disaster recovery strategies, proper planning, better scopes and collaborations are limited in India for which better facilities are not made available to the citizens. Moreover, Government plans and strategy also plays a vital role in the proper implementation and success of e-Governance Projects in India. The Government plans are not based on scientific weightage of various parameters for the success of e-Governance.

The above discussion in the results and comparison section gives the various ranking of alternatives and criteria. These priority ranking of criteria and alternatives are useful for better decision making approach in the Governance system as they are analysed by taking multiple criteria from all sectors of implementation starting from planning and governance to availability of resources and ICT support staff for helping citizens to become aware of the e-Governance Services. This paper mainly aims to provide the priority order ranking of the attributes that are possibly held responsible for healthy decision making process for real e-Governance in India so that it will reach enmass pan India to reach the unreached.

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