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Effect of Different MCDM Techniques and Weighting Mechanisms on Women Vulnerability Index

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Abstract: Crime against women is a chronic issue that saddens society and needs to be carefully addressed. The states of India exhibit significant variations in the incidence of criminal behavior. We created a novel index in our previous research to determine how vulnerable Indian women are to crimes in various Indian states and union territories. The Women Vulnerability Index (WVI) assessed women's vulnerability to crime across all regions of the country. A set of alternatives is ranked using Multi-Criteria Decision Making (MCDM) procedures based on a range of criteria or objectives. There are different MCDM techniques available to choose from. Also, many weighting schemes exist to assign relative importance or weight to the indicators. The task of selecting the MCDM technique for one's application is a big challenge. A bigger challenge is to select the appropriate weighting mechanism as well. This study's primary goal is to evaluate the viability and efficacy of several MCDM approaches in conjunction with various weighting systems in order to identify the Indian state with the greatest rate of crime against women. We apply different MCDM techniques on crime data to compute WVI. Also, we see the effect of using six different methods to assign weights to the factors on the values of WVI. MCDM methods are very popular these days and are being used in a lot of domains for decision making applications. Our paper will guide all such stakeholders and researchers to choose an appropriate MCDM technique and weighting method for their applications.

Keywords - MCDM, TOPSIS, MABAC, VIKOR, CRITIC, GINI Weights

1. Introduction

Crime against women is a persistent problem which needs urgent attention. There is a lot more violence against Indian women than what may seem. The Indian government has made putting an end to violence against women a top priority, which aligns with the UN Sustainable Development Goals on gender equality. There is a need to rank Indian states based on crime rate in these states. The frequency of criminal activity varies greatly throughout India's states. Recently, in our earlier paper [1] we had constructed a novel index using MCDM for calculating the vulnerability of Indian women to crime in different states and union territories of India. The Women Vulnerability Index (WVI) assessed how vulnerable Indian women were to crime in every part of the country. When assessing data by taking into account a variety of criteria and factors, MCDM is a useful tool. This method enables decision-makers to consider several aspects at once, leading to a more thorough comprehension of the problem's complexity.

To select an option from a list of options based on a variety of criteria or goals, MCDM approaches are applied. Essentially these techniques seek to identify the optimal option by considering multiple criteria during the selection process. These criteria must be considered simultaneously or together to make the choice between alternatives. The problem of selecting an alternative after carefully weighing each of the factors as per a preference level can be done by the human mind also. Typically, when done by human beings it will be based on an intuitive approach which may be biased as well. But the use of MCDM allows us to use a formal structure with a mathematical background to solve this decision-making problem and automate the algorithm as well. Many MCDM techniques are available.

A challenging task is to decide on the relative importance of various criteria. The information or knowledge about the weights to be used for different criteria is completely unknown. The success of the MCDM technique would depend highly on these assigned weights. It is important to note that the ranking of various alternatives is highly dependent on the various weights assigned to the factors and the MCDM technique used. Different weights or criteria would yield different total scores, which may lead to an equal ranking or the opposite. The weights that are allocated would also take into account the decision makers' preferences. The output will surely depend on this relative importance or weights chosen for each of the factors. These may also be referred to as preference values for the various factors. Using MCDM the alternatives will be assigned a score based on how each of them perform in each of the criteria, measured according to the preference

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values. This paper's primary goal is to evaluate the suitability and efficacy of the MCDM techniques for identifying the Indian states where women are most at-risk for crime. In addition to the TOPSIS ("Technique for Order of Preference by Similarity to Ideal Solution") model that was used in the earlier article, four additional MCDM methods were chosen from the most popular ones in the literature[2]. These methods include VIKOR, MABAC, CODAS, and MAIRCA. The purpose of this process was to determine if a different methodology would be more appropriate for the ranking of Indian states in the future. Along with this we also aimed at finding the most suitable MCDM method for our analysis.

We selected the methods, such that there is at least one representation from all the different normalization techniques[3]. CODAS method is based on linear normalization whereas TOPSIS is based on vector normalization. MABAC, MAIRCA and VIKOR all three are based on the most used Max-Min linear normalization method. The probability that the results obtained from the methods can be the same is not ruled out [4].

Any MCDM problem requires careful consideration of weighting procedures since they directly affect the accuracy and reliability of the decision outputs. Each weighting strategy has a distinct feature that produces different weights associated with the criterion, resulting in rankings that impact the entire order rather than just the best choice. Earlier we had chosen equal weighting method for our analysis. We further select five more weighting methods for our study. These include entropy method, standard deviation, Gini index, angle method and criteria importance through inter-criteria (CRITIC) index. We ran all combinations of selected five MCDM methods and six different weighting methods on the crime data. All states and union territories of India were then scored and ranked. Women vulnerability Index was computed for all combinations.

The outcomes attained using various MCDM techniques and weighting methods are examined and contrasted statistically. There is also a discussion of the various methodological methods' advantages and disadvantages. MCDM methods are very popular these days and are being used in a lot of sectors, including engineering design and finance. Our paper will guide all such stakeholders and researchers to choose an appropriate MCDM method and choose a weighting method for assigning weights for various indicators when using MCDM techniques.

Several additional articles tried to compare various MCDM techniques in relation to various application domains. Unfortunately, despite our best efforts, we were unable to locate any comparison analysis of MCDM approaches for determining the location of most susceptible to crime for women. Our paper's unique contribution makes it stand out.

2. MCDM Model

MCDM is essentially a tool to assist people in decision making without involvement of human bias. Use of MCDM techniques results in a more transparent and consistent decision making. There are many applications of MCDA/MCDM tools. It can be used to rank applicants applying for a job. Prioritizing clients/students/patients in need of any service/scholarship/treatment or even prioritizing new business projects. The MCDM process starts by defining the problem followed by selection of the alternatives/options and the criteria/factors for the problem at hand. Decision matrix is then created. Weights are assigned to all the factors/criteria. Any appropriate MCDM technique is later used to rank/choose the best alternative. Figure 1 shows the MCDM process.

Fig 1: Overview of MCDM process

The key components of the MCDM model are **Alternatives/Options** which includes all the options (at least two) available for selection. Another major component is the different **Factors/Criterions** which form the basis of selection. We need to specify the impact of the factors in terms of it being positive or negative called **Benefit/Cost.** In the last, we have the relative importance of the criteria called **Weights**. Considering these key components, a decision matrix is formed.

A finite set of m choices, written as $A = \{A_i \mid i = 1,..., m\}$, that are assessed in accordance with n criteria, expressed as $C = \{C_j \mid j = 1,..., n\}$, defines an MCDM problem. The criteria may indicate a cost or a benefit criterion. It is ideal to maximize a benefit criterion, meaning that the better an alternative is, the higher it scores on this criterion; conversely, lower values are preferred for cost criteria [5]. Additionally, a weight is provided to each criterion to indicate its relative importance. These weights are often normalized so that their sum equals one [6].

The MCDM problem now can be easily stated in matrix form as shown in Table 1, where rows and columns represent the alternatives and the criteria, respectively. The score of the option A_i in relation to the criterion C_j is represented by each element ($entry_{ij}$) in the decision matrix.

	Criteria C_1	**Criteria C_2**	**Criteria C_3**	**….**	**Criteria C_n**
Alternative A_1	entry $_{11}$	entry $_{12}$	entry $_{13}$		entry $_{1n}$
Alternative A_2	entry $_{21}$	entry $_{22}$	entry $_{23}$		entry $_{2n}$
Alternative A_3	entry $_{31}$	entry $_{32}$	entry $_{33}$		entry $_{3n}$
:					
Alternative A_m	entry $_{m1}$	entry $_{m2}$	entry $_{m3}$		entry $_{mn}$

Table 1: Decision matrix for MCDM problem

The objective of the task is to rank the options according to their total performance value, which is ascertained by multiplying their scores by their weights [7]. This task lends itself to a large variety of algorithms that correlate to the many MCDM techniques that are currently in use[8].

3. MCDM Methods Used

Over the past few decades, various writers have developed or refined a variety of MCDM approaches. The degree of algorithmic complexity and the criterion weighting techniques used in these strategies vary [9]. Some methods are based on pair wise comparison, while some take into consideration preferences. Few others take distance from ideal solutions and many others are based on aggregation of these. Each MCDM method has its own advantages and disadvantages. Experience shows that there is no MCDM technique that can deal with all multicriteria problems [10],[11]. MCDM methods have their applications in varied fields like engineering, disaster management, medicine, computer science, mathematics and many more.

A wide range of decision-making methods exist in literature too. In this paper, five distinct methods have been used on crime against women data. These methods have been used to compute the women vulnerability index of different states of India and find the states which are safe for women to live in. The methods used in this study include TOPSIS (distance based), VIKOR (works under compromising situations), MABAC (area-based comparison and approximation method), CODAS (based on Euclidean and Taxicab distance), and MAIRCA (based on gap between ideal and empirical ratings). The following section explains the methods in brief:

3.1 TOPSIS

This method developed by Hwang et al. [12] ranks the options using Euclidean distance between an option and the ideal positive and negative solution. Both positive and negative aspects of factors and conflicting objectives are taken into account. Additionally, it has no restriction on how many factors are identified for input. Also, it neither considers the correlation of attributes nor the uncertainty or imprecision in the decision data.

3.2 VIKOR: (VIseKriterijumska Optimizacija IKompromisno Resenje)

Opricovic created a compensatory version of TOPSIS which uses linear normalization approach to minimize the distance to the best solution [13]. Rankings of options are based on how near the optimal answer they are. The solution found using the VIKOR method of adjusted ranking, gives the "majority" the highest "group utility" and the "opponent" the least amount of personal regret [14]. This method is used to solve problems where criteria are conflicting and are with different units.

3.3 Multi-Attribute Border Approximation Area Comparison (MABAC)

MABAC proposed by Pamucar et al. [15] works by finding the separation among every option and the border approximation area (BAA). After that, it makes use of the distance to choose the best solution among a range of possibilities. The results obtained by this method are consistent even if the type of criteria or the units of measurement used to show the criteria values of the alternatives change. There is no restriction on count of factors and options.

3.4 CODAS: COmbinative Distance based ASsessment

The method developed by [16] uses Euclidean and Taxicab distance both to find performance of an alternative. These distances from the negative-ideal point serve as a gauge for an alternative's overall effectiveness. The taxicab distance is used to compare two options if their Euclidean distances are extremely near to one another.

3.5 MAIRCA: (Multi Attributives Ideal-Real Comparative Analysis)

MAIRCA developed by [17] compares theoretical and empirical ratings to find the difference between them. By computing the difference between the two for each choice, the approach seeks to determine the better option. The optimal option is the one with the lowest utility score. The method can be applied on datasets having criteria which can be qualitative and/or quantitative.

4. Weighting Methods Used

The selection of weighting techniques is necessary for any MCDM problem as it directly affects the precision along with dependability of the solution. Weights attached to the criterion are produced by the unique feature of each weighting approach which results in rankings that affect the full order rather than simply the best option. There are three types of weighting methods viz. subjective, objective and hybrid.

The decision-makers choice influences how criteria weights are determined in subjective techniques. They subjectively evaluate and ascertain the weight of each criterion provided. This is possible only if they have access to sufficient information regarding the significance of the criteria. But in cases when priorities are not clearly defined, objective weighting techniques come handy. While the first option seems helpful, it is unable to ensure that the rankings are robust. In contrast, the second option, which solely relies on the decision matrix, may address this issue by implementing the proper form. When establishing the relative importance of the criteria, objective methods use mathematical algorithms. The hybrid approach combines objective and subjective techniques.

Subjective methods include "direct ranking," "point allocation," "pair wise comparisons," and SMART ("Simple Multi-attribute Ranking Technique"). These approaches primary drawback is the decrease in efficiency with the increase in options. Decision-makers must mentally represent their preferences, and as the number of criteria they use increases, their preferences become less accurate.

On the other hand, the criteria weights in objective weighting procedures are not influenced by the choice of the decision-makers and are calculated by employing a particular computational technique or a mathematical function like entropy, standard deviation, mean, angular distance etc. on the original information gathered. The section below explains these methods:

4.1 Equal Weight

When there is insufficient information available to make a judgment, or when the decision maker is not providing any information at all, the equal weight (same priority) approach is typically taken in MCDM [18]. The Equal Weight approach focuses on all indicators being equal while ignoring the variety and structure of the data. This method assumes that all criteria are of equal importance. It is the most straightforward method of giving weights to criteria because it divides the weights equally among all the criteria. It assumes that every criterion is equally important.

4.2 Standard Deviation

This technique establishes the weights of the criteria based on their standard deviations according to Jahan et al. [19]. This approach gives low weights to a criterion if their values are comparable among alternatives. When criteria’s performance values for all alternatives deviate somewhat, it indicates that the attribute has a minor but significant impact on the prioritization process. But a criterion is crucial in determining which alternative is best if it causes the performance values of all the alternatives to differ noticeably. So, to rank the alternatives, a feature is given a lower weight if its attribute values are similar across alternatives; otherwise, a feature that deviates more from the normal is given a higher weight, regardless of how important it is. Specifically, when every possible option has a similar score for a particular quality, that attribute is considered to be insignificant. Stated otherwise, a very low weight should be given to such a characteristic. The variation in the property values may be calculated with the standard deviation.

4.3 Entropy method

Shannon's entropy weight method (EWM) [20] is used to measure value dispersion It essentially assigns weights by considering the entropy provided by the criterion values. Entropy can be thought of as a measure of its disorder or impurity or randomness in values. As per the principles of information theory, criteria that have a lower information entropy are considered to give more information and are therefore of more significance. A higher weight is assigned to the attribute if the information entropy performs comparatively poor[21]. However large number of zero values will make EWM prone to distortion leading to large index weight.

4.4 The Gini Index

It is also known as the Gini impurity. This calculates the likelihood that a given variable would be incorrectly classified when selected at random. It reduces the amount of entropy in the dataset. Its value ranges from zero to one, where zero signifies pure class. On the other hand, one denotes that elements are sporadically distributed among many classes which are the case of “impure”. For some groupings, a Gini Index of "0.5" indicates that the things are distributed equally. The stability of the ranking criteria is assessed using the Gini index. When two options are compared, the one with a lower Gini index value is preferable.

4.5 Criteria importance through inter-criteria (CRITIC)

This method proposed by Diakoulaki [22] considers not only the correlation amongst the factors but also their standard deviation. The information content is quantified with the help of contrast intensity and conflict measurement which are evaluated using standard deviation and correlation respectively. The degree of variability linked to each criterion's local score is reflected in the contrast intensity. A criterion is given a larger weight when it has a higher contrast intensity or standard deviation. A criterion is thought to provide more interesting or significant information if its scores vary more between its alternatives, and thus are given more importance or weight in comparison to the criterion having uniform scores. In an MCDM situation conflicting criteria are typically present in the options. The CRITIC technique considers relationships that are in conflict by using the Pearson correlation coefficient, which has a range of -1 to 1. A criterion with strong positive correlation to other criteria is thought to be insignificant in the decision system overall and does not provide any more information. Essentially higher weight is assigned to a criterion with higher conflict or lower redundancy.

4.6 Angle

Shuai et. al. [23] proposed a novel technique to assign weights. It is based on the idea that the angle between two choices vectors in the decision space might express how different they are from one another. When using this approach, criteria with similar evaluated option values are given a low weight, while criterion with different alternative performances are given a high weight.

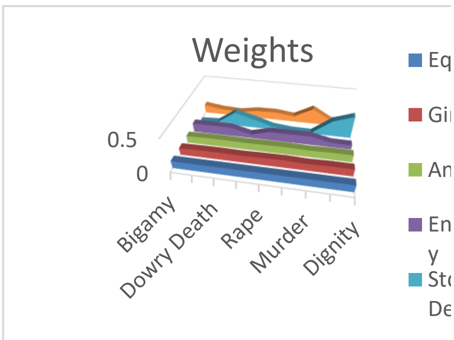
5. Experiment and Results

The data utilized in this study is gathered from the National commission for Women website (ncw.gov.in). We have pre-processed the data that included dealing with the null values present in the data. The dataset finally constructed was used to compute Women Vulnerability Index (WVI) in our earlier paper. WVI was computed by applying TOPSIS on actual crime incidents. The scores for each area were calculated by considering nine indicators which were the actual number of different crimes reported in each of those areas. Further while calculating the scores, we had assigned equal weights to each of these indicators. In this paper we calculated scores for all Indian states and union territories for all the chosen MCDM techniques and the chosen weighting methods. The results obtained were compared and analyzed.

Table in Figure 2(a) shows the weights for all the factors derived from various weighting methods. Equal weight method assigns equal weight for all the factors according to the formula (1/n), where n is number of criteria. Weights computed by various methods like Gini, Angle, entropy, Standard Deviation and CRITIC are shown in Figure 2(a). As shown the criteria's weights are dispersed fairly. Visual representation of the weights is shown in Figure 2(b).

	Equal	Gini	Angle	Entropy	Std. Dev.	CRITIC
Bigamy	0.111111	0.105501	0.106648	0.133962	0.008733	0.124237
Divorce	0.111111	0.112282	0.113373	0.133962	0.023061	0.08477
Dowry Death	0.111111	0.113126	0.113049	0.133962	0.207354	0.069799
Harassment	0.111111	0.107609	0.108826	0.059003	0.131779	0.115414

a



b

Fig 2: Weights obtained by various weighting methods

Using the five MCDM approaches examined in this paper, we ranked the alternatives/states using the criteria weights shown in Figure 2(a) on the dataset. The states are ranked according to the final score values obtained by applying the five MCDM algorithms, as shown in Table 2. These final scores are used to compute WVI.

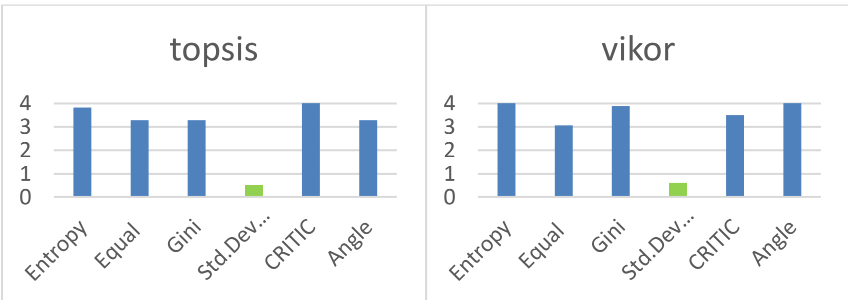
Table 2 demonstrates how the weighting strategy and the decision-making process affect the ranks of the options which are available. Additionally, this supports the findings of other published investigations [24],[25]. But again, this table's results highlight an intriguing point that all five MCDM methods which were studied show that women in India are most vulnerable in UP with rank 1 in all columns followed by Delhi at rank 2 and Rajasthan at rank 3. We also compute the deviation of WVI obtained by these five methods with that of estimated WVI (E-WVI). To find the best weighting method, graphs for each algorithm for all weighting methods were plotted as shown in Figure 3. It can be seen that amongst all methods, standard deviation method of weighting produces the least deviation/root mean square error. To find the best MCDM method, graphs were also plotted separately for each weighting method as shown in Figure 4. It is seen that MABAC outperforms all its opponents for all the weighting methods and has the least root mean square error.

We also validated the results by computing the correlation between ranks generated by E-WVI and obtained WVI. We found that for all the MCDM methods correlation obtained using standard deviation method was the maximum as shown in Figure 5(a). Amongst all the MCDM techniques studied, MABAC has the highest correlation for all weighting methods as shown in Figure 5(b) again proving its efficacy against other techniques.

	Equal Weight					Entropy					Gini					Angle					CRITIC					Standard Deviation				
state	M1	M2	M3	M4	M5	M1	M2	M3	M4	M5	M1	M2	M3	M4	M5	M1	M2	M3	M4	M5	M1	M2	M3	M4	M5	M1	M2	M3	M4	M5
AP	16	17	17	17	17	15	17	15	16	16	16	17	17	17	17	16	17	17	17	17	16	16	15	15	15	15	15	15	17	17
AR	26	28	26	28	28	26	27	26	27	27	26	30	26	29	29	26	29	26	28	28	26	28	27	28	28	32	32	32	32	32
AS	21	20	21	21	21	20	19	20	20	20	21	19	21	21	21	21	19	21	21	21	20	20	20	20	20	22	22	22	22	22
BR	5	6	5	5	5	4	6	5	5	5	5	6	5	5	5	5	6	5	5	5	4	4	4	5	5	5	5	6	6	6
CG	14	16	14	15	15	14	16	14	14	14	14	16	14	15	15	14	16	15	15	15	14	14	14	14	14	17	17	17	16	16
GA	24	25	24	25	25	24	25	24	25	25	24	25	24	25	25	24	25	24	25	25	24	24	24	24	24	24	24	24	24	24
GJ	17	14	15	14	14	17	14	17	15	15	17	15	15	14	14	17	15	14	14	14	17	17	17	16	16	16	16	16	15	15
HR	4	4	4	4	4	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6	6	5	4	4	3	3	3	3	3
HP	19	19	19	19	19	19	20	19	19	19	19	20	19	19	19	19	20	19	19	19	19	19	19	19	19	20	20	20	20	20
J&K	22	21	22	22	22	22	21	22	22	22	22	21	22	22	22	22	21	22	22	22	22	22	22	22	22	21	21	21	21	21
JH	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	12	13	12	12	12
KR	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	12	13	13	13
KE	20	22	20	20	20	21	22	21	21	21	20	22	20	20	20	20	22	20	20	20	21	21	21	21	21	19	19	19	19	19
MP	6	5	6	6	6	6	5	6	6	6	6	5	6	6	6	6	5	6	6	6	5	5	6	6	6	6	6	5	5	5
MH	7	7	7	7	7	7	8	7	7	7	7	8	7	7	7	7	8	7	7	7	7	7	7	7	7	7	7	7	7	7
MN	29	31	29	31	31	29	29	28	29	29	29	26	29	31	31	29	26	29	31	31	30	31	30	31	31	31	31	31	31	31
MG	31	30	31	30	30	31	31	31	31	31	31	31	31	30	30	31	31	31	30	30	31	30	31	30	30	28	27	28	27	27
MZ	35	35	35	35	35	34	34	34	34	34	35	35	35	35	35	35	35	35	35	35	35	35	35	33	35	35	34	35	35	35
NL	32	33	32	33	33	32	32	32	32	32	32	33	32	33	33	32	33	32	33	33	32	32	32	32	32	34	35	34	34	34
OR	18	15	18	18	18	18	15	18	18	18	18	14	18	18	18	18	14	18	18	18	15	15	16	17	17	18	18	18	18	18
PB	12	12	12	12	12	12	12	12	12	12	12	11	12	12	12	12	11	12	12	12	12	12	12	12	12	11	11	11	9	9
RJ	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4
SK	33	32	33	32	32	33	33	33	33	33	33	32	33	32	32	33	32	33	32	32	33	33	33	33	33	33	33	33	33	33
TN	10	11	10	10	10	10	11	10	10	10	10	12	10	10	10	10	12	10	10	10	10	10	10	10	10	10	10	10	10	10
TL	15	18	16	16	16	16	18	16	17	17	15	18	16	16	16	15	18	16	16	16	18	18	18	18	18	14	14	14	14	14
TR	28	26	27	26	26	27	26	27	26	26	28	27	27	26	26	28	27	27	26	26	27	26	26	26	26	26	26	26	26	26
UP	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
UK	8	8	8	8	8	8	7	8	8	8	8	7	8	8	8	8	7	8	8	8	8	8	8	8	8	8	8	8	8	8
WB	11	10	11	11	11	11	10	11	11	11	11	10	11	11	11	11	10	11	11	11	11	11	11	11	11	9	9	9	11	11
A&N	27	27	28	27	27	28	30	29	30	30	27	28	28	27	27	27	28	28	27	27	28	29	28	29	29	27	29	27	28	28
CH	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23
D&N	30	29	30	29	29	30	28	30	28	28	30	29	30	28	28	30	30	30	29	29	29	27	29	27	27	30	30	30	29	29
D&D	34	34	34	34	34	35	35	35	35	35	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	29	28	29	30	30
LK	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
DL	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
PC	25	24	25	24	24	25	24	25	24	24	25	24	25	24	24	25	24	25	24	24	25	25	25	25	25	25	25	25	25	25

M1 : TOPSIS M2: VIKOR M3 : CODAS M4: MABAC M5: MAIRCA

Table 2: Ranks obtained for all schemes and weighting methods



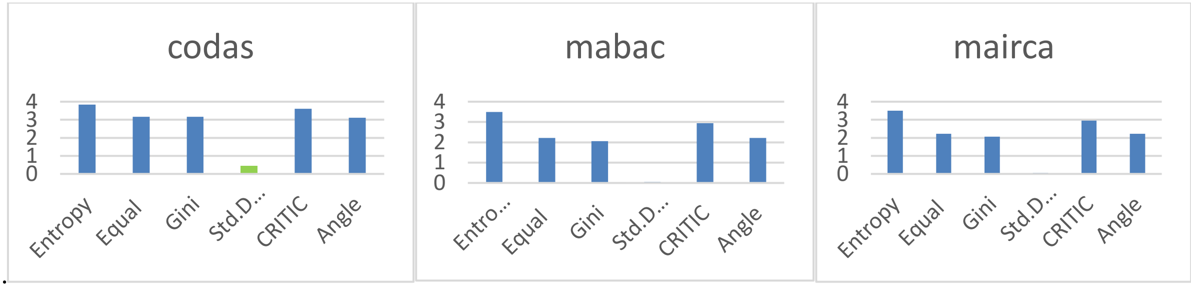
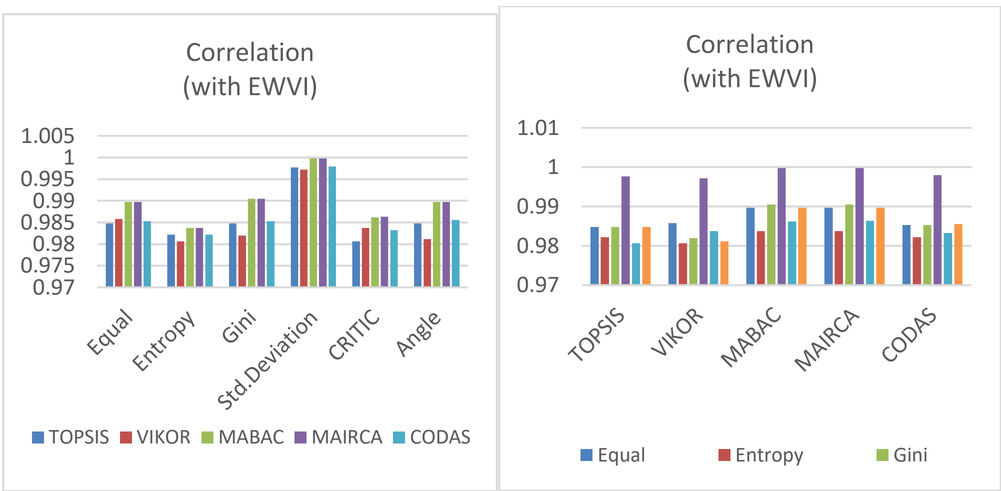


Fig 3: Performance of weighting methods on MCDM methods

Fig 4: Performance of MCDM methods on weighting methods



a b

Fig 5: Correlation for all schemes and weighting methods

6. Conclusion

Essentially, both weighting mechanism and decision-making process employed affect the ranking of alternatives results. All the studied MCDM techniques (MABAC, MAIRCA, VIKOR, TOPSIS and CODAS) were applied on crime data. According to all the algorithms women are most vulnerable in Uttar Pradesh followed by Delhi and then Rajasthan. We saw that of all the weighting methods, standard deviation weighting method gives the best results. We also saw that MABAC method having least mean square error outperforms all other methods for all the weighting methods used. Furthermore, it should be mentioned that an MCDM solution's efficacy depends on the problem and the available data.

References

[1] *Women Vulnerability Index (WVI): Multi Criteria Decision Making Approach.* **Aggarwal, G, Bansal, M and Aggarwal, S.** 21s, 2024, International Journal of Intelligent Systems and Applications in Engineering, Vol. 12, pp. 1232–1238.

[2] *Statistical and analytical comparison of multi-criteria decision-making techniques under fuzzy environment.* **Hamed, Z, S, et al.** 2016, Operations Research Perspectives, Vol. 3(c), pp. 92-117.

[3] *Comparison of Multi-Criteria Decision Making Methods Using The Same Data Standardization Method.* **Tien, D, Trung, D and Thien, N, V.** 2, 022, Strojnícky časopis - Journal of Mechanical Engineering, Vol. 72, pp. 57-72.

[4] *A comparative study on material selection of microelectromechanical systems electrostatic actuators using Ashby, VIKOR and TOPSIS.* **Yazdani, M and Payam, A, F.** 2015, Materials & Design, Vol. 65, pp. 328-334.

[5] *A comparative analysis of multi-criteria decision-making methods.* **Ceballos, B, Lamata, M, T and Pelta, D, A.** 2016, Progress in Artificial Intelligence.

[6] *The Impact of Aggregating Benefit and Cost Criteria in Four MCDA Methods.* **Triantaphyllou, E and Baig, K.** 2, 2005, IEEE Transactions on Engineering Management, Vol. 52, pp. 213-226.

[7] *A Review of Multiple Criteria Analysis for Water Resource Planning and Management.* **Hajkowicz, S and Collins, K.** 2007, Water Resources Management, Vol. 21, pp. 1553-1566.

[8] **Ballestero, E and Romero, C.** *Multiple criteria decision making and its applications to economic problems.* Netherlands : Kluwer Academic Publishers, 1998.

[9] **Laaribi, A.** *SIG et analyse multicritère.* Paris : Hermès Science Publications, 2000.

[10] *Multiple Attribute Decision Making: Methods and Applications.* **Hwang, CL and Yoon, K.** 1981, Lecture Notes in Economics and Mathematical Systems.

[11] *Multicriteria Optimization of Civil Eng. Sys.* **Opricovic, S.** 1998, Faculty of Civil Engineering.

[12] *Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS.* **Opricovic, S and Tzeng, G, H.** 2, 2004, European Journal of Operational Research, Vol. 156, pp. 445-455.

[13] *The selection of transport and handling resources in logistics centers using Multi-Attributive Border Approximation area Comparison (MABAC).* **Pamučar, D and Ćirović, G.** 6, 2015, Expert Systems with Applications, Vol. 42, pp. 3016-3028.

[14] *A new combinative distance-based assessment (CODAS) method for multi-criteria decision-making.* **Ghorabaee, M, K, et al.** 3, 2016, Econ. Comput. Econ. Cybern. Stud. Res., Vol. 50, pp. 25-44.

[15] *New hybrid multi-criteria decision-making DEMATEL -MAIRCA model: sustainable selection of a location for the development of multimodal logistics centre.* **Pamuca, D, S, Tarle, S, P and Parezanovi, T.** 1, 2018, Economic Research-Ekonomska Istrazivanja , Vol. 31, pp. 1641-1665.

[16] *Review on multi-criteria decision aid in sustainable energy decision-making.* **Wang, J. J, et al.** 2009, Renewable and Sustainable Energy Reviews, Vol. 3, pp. 2263-2278.

[17] *A framework for weighting of criteria in ranking stage of material selection process.* **Jahan, A and al., et.** 1-4, 2012, International Journal of Advanced Manufacturing Technology, Vol. 58, pp. 411-420.

[18] *Prediction and entropy of printed English.* **Shannon, C, E.** 1951, Bell system technical journal, pp. 50-64.

[19] *Road safety risk evaluation by means of improved entropy TOPSIS–RSR.* **Chen, F, Wang, J and Deng, Y.** 2015, Saf Sci, Vol. 79, pp. 39-54.

[20] *Determining objective weights in multiple criteria problems: The CRITIC method.* **Diakoulaki, D, Mavrotas, G and Lefteris, P.** 7, 1995, Comp. Operate. Res, Vol. 22, pp. 763-770.

[21] *A new angular method to determine the objective weights.* **Shuai, D, et al.** 2012. 24th Chinese control and decision conference (CCDC).

[22] **Aytekin, A.** The distances and references-based solution approach for multi-criteria decision problems. s.l. : PhD thesis, Anadolu University, Graduatc School of Social Sciences, 2020.

[23] *A Multi-Criteria Decision-Making Approach.* **Enrique, B, Perez-Gladish, B and Garcia-Bernabeu, A.** 2015, International Series in Operations Research and Management Science.

[24] *Comparative Analysis of Multicriteria Decision Making Methods for Postgraduate Student Selection.* **Altunok, T, et al.** 2010, Eurasian Journal of Educational Research, pp. 1-15.

[25] *Towards Objectification of Multi-Criteria Assessments: A Comparative Study on MCDA Methods.* **Bączkiewicz, A., et al.** 2021. Proceedings of the 16th Conference on Computer Science and Intelligence Systems (FedCSIS).