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Women Vulnerability Index (WVI): Multi Criteria Decision Making Approach

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Abstract: Crime against women, a never-ending issue is a sad reality that demands focused attention. The occurrence of crimes in different states in India varies a lot. Multi-Criteria Decision Making (MCDM) method, called TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) is applied on real occurrences of crime to develop women vulnerability index (WVI). This index measures the susceptibility of women to crime in any region of India. This marks the first instance of applying MCDM technique (TOPSIS) to derive such an index for crime against women. The index will equip the law enforcing agencies and various NGOs to assess the susceptibility of Indian women in different regions and take appropriate action for mitigation of such crimes to create a safe environment for women. We find that states like Mizoram, Nagaland, Sikkim in northeast India and Lakshadweep Islands in southern India have very low values of the index and are the safest places for women. On the other hand, Uttar Pradesh, Delhi, Haryana, Rajasthan, and Bihar are Indian states where women are most susceptible to crime having very high values of WVI.

Keywords: *Women Vulnerability Index, Crime against Women in India, Multiple Criteria decision making, TOPSIS.*

1. Introduction

All throughout their lives women are subjected to different kinds of crime no matter what caste they belong to, what religion they follow or what their economic status is. They face these crimes not only outside their homes but also within the boundaries of their home (1). Despite all efforts and measures taken by the authorities, incidents of crime against women are always increasing. The National Commission of Women, an organization in India reports the number of crimes registered by females under various categories since 2001. However, very few people have tried to analyze that data to bring out a formal quantifiable measure like WVI along with using a MCDM technique to do the same. The average number of crimes reported against women as per NCW in last few years are in the range of thirty thousand. These figures are alarming. We cannot also ignore the number of cases which have not been reported due to social pressure.

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The authors (2) lay stress on the incomplete reporting of crime. Also, they feel that even though the occurrence of crime is increasing in our lives yet there are few people who are involved in study of crime. In their paper, they study the official and published data to draw meaningful inferences for future work. The authors in (3) have used tools like regression analysis on crime data from NCRB to study trend and regional variation of crime against women. The authors in (4) have analyzed data from NCRB to find pattern and trends in crimes committed on Indian women. Plan India (5), an initiative of National Institute of Urban Affairs; try to design a gender vulnerability assessment tool. This tool will aid the authorities in assessing the status of girls and women in India. The paper (6) studies the accessibility of a place as one of the conditions related to crime risk vulnerability using tools like space syntax analysis. Authors in (7) develop a composite index to classify neighbourhoods based on vulnerabilities of localities. Again in their paper (8), authors define vulnerability of a place in terms of its accessibility. The authors assess vulnerability on the basis of their study of a small sample state and using information based on word of mouth, Few authors in (9), (10), (11), (12) have worked in computing vulnerability of women to domestic violence.

Multiple criteria decision making (MCDM), a valuable tool in analyzing crime data by considering various criteria and factors, allows decision-makers to weigh multiple factors simultaneously. This will facilitate in a

better and comprehensive understanding of the nature of crime. Authors (13), have studied research from 1977 involving MCDM techniques in the last forty-four years. For this the authors have studied bibliographic data of available papers on platforms like SCOPUS and WOS. They found that 33,201 authors have written 23,494 documents on multi-criteria methods. This indicates the growing importance of use of such methods for effective decision-making.

In our paper, we suggest a novel index for quantizing crime against women in India. We have used dataset for the last twenty-two years for constructing such an index. As far as we know, this is the first attempt to use MCDM method for computing index for crime against women data. We used the MCDM technique called Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) to construct this index. TOPSIS was developed by Ching-Lai Hwang and Yoon (14). In TOPSIS, scores are assigned to various alternatives based on their distance of each alternative from their ideal. The ideal solution should be closest to the positive ideal and farthest from the negative ideal. The scores are then ranked from best to worst.

Our research carefully assesses the vulnerability of women within specific Indian states. We attempt to provide a metric to measure the vulnerability of women to crime at a place. This comprehensive evaluation takes into consideration various crime types prevalent in each state. This index considers previous statistics of crime against women. A woman is more susceptible in a region having higher index value. This research unveils the most susceptible Indian states to crimes against women, thus creating an awareness requiring concrete action from authorities for crime reduction techniques, offering a compass for policymakers and law enforcement agencies alike thus empowering them.

The Women Vulnerability Index (WVI) will serve as a critical tool in assessing and understanding the susceptibility of women in each area to criminal activity. WVI will become a valuable resource by providing insights to take actions to develop mitigation strategies against crimes targeting women. It will aid policymakers, law enforcement agencies and community leaders in identifying areas that require targeted interventions and resources to mitigate crime risks. This strategic approach enables the implementation of preventive measures and the allocation of resources to address underlying social issues that may contribute to criminal behavior. Women Vulnerability Index, therefore, will play a pivotal role in taking active steps to enhance women safety and create more women friendly environment.

2. Motivation and Methodology

Authors in (1) have used Principal component analysis method to compute WCSI for 28 Indian states and 7 union territories. The computation is done based on nine different crimes against women for the year 2012. The major findings of the analysis were that West Bengal and Assam were ranked highest on women susceptibility to crime followed by Tripura and Delhi and on the other hand Goa and Mizoram were found to be the safest states. They have used PCA method for computing index by considering data for one year only. Principal component analysis has also been used by (15) wherein they evaluate the impact of female labor force participation on women vulnerability index.

Authors in paper (16) use NCRB data for ten years from 1991 to 2001 to develop an index for crime considering seven different crime types. Though they construct a violent crime index but their work is not focusing on crime against women. Authors in (17) have used fuzzy MCDM approach in crime analysis. They studied the linkage of a pair of crimes being committed by the same culprits. Authors in (18) have also used MCDM method to assign ranks to Indian states based on accidental data. The model evaluates the road safety performance of these states.

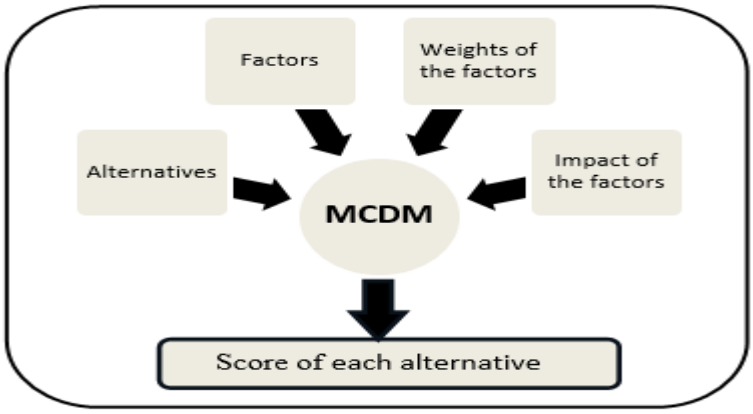

Fig 1: MCDM

A popular MCDM method, TOPSIS is applied for choosing the best solution from available options based on evaluation of various criteria. MCDM method (as shown in Figure 1) involves major components such as Alternatives, Attributes/Factors/Criteria, weights /importance of these criteria and the impact/benefits of these factors on the alternatives. Essentially this method selects the best alternative out of the available alternatives based on the scores computed for them.

TOPSIS uses a mathematical procedure to assign scores based on its distance from the best and the worst solution. Since the method is mathematical, it is free from any human bias which may arise due to manual decisions.

In our paper, we suggest an index (novel as far as we know) for quantizing crime with a special focus on crime against women only. We have used dataset for the last twenty-two years for constructing such an index. As far as we know, we are the first ones to use MCDM method, TOPSIS for computing WVI for crime against women.

Input

- m alternatives
- n criteria (aij is the value for criterion j for each alternative i)
- T be the set of cost/benefit criteria
- W be the set of weights for each criterion

Output

- Alternative scores

Process

• A decision matrix with normalized scores is constructed for homogeneous comparisons over different criteria. These normalize scores are given as

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum a_{ij}^2}}$$ For i ranging from 1 to m and j ranging from 1 to n (1a)

• Weights are assigned to the matrix developed in above step. Let the weights be W given as:

$w_j \in W$ for $j = 1, \ldots, n$

• Each column of the normalized decision matrix is multiplied by its associated weight

$v_{ij} = w_j * r_{ij}$

• Maximum and minimum value of each criterion is found

• Positive ideal solution is calculated S^+ (v_j^+ is the set of largest values i.e. with respect to each criterion)

$S^+ = \{v_1^+, v_2^+, \ldots, v_m^+\}$

• Negative ideal solution S^- (Smallest values set v_j^- with respect to each criterion) is calculated

$S^- = \{v_1^-, v_2^-, \ldots, v_m^-\}$

Where,

v_j^+ = {maximum (v_{ij})} when j is positive impact criterion

= {minimum (v_{ij})} when j is negative impact criterion

v_j^- = {maximum (v_{ij})} when$j$ is negative impact criterion

= {minimum (v_{ij})} when j is positive impact criterion

• S_i^+ and S_i^-, the separation measures are calculated for each alternative i

Where:

• S_i^+ is the estimate of separation from S^+ and

$$S_i^+ = \sqrt{\sum_{j=1}^{m} (v_j^+ - v_{ij})^2} \forall i = 1, 2, \ldots, n$$

• S_i^- is estimate of separation from S^-.

$$S_i^- = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_j^-)^2} \forall i = 1, 2, \ldots, n$$

• Calculate the closeness coefficient to the ideal solution C_i for each alternative i, where

$C_i = \frac{s_i^-}{s_i^- + s_i^+}$ where, value of $C_i$is between 0 an1 (both inclusive)

• C_i for each alternative i thus computed are the scores for each alternative which can be ranked for the best or the worst alternative

Fig 2: MCDM algorithm

Our model takes as input a list of states and union territories (alternatives) and a set of factors (crime against women) based on which we do our computation. Weights for each factor are calculated using mean weight method. In our algorithm, all the crimes have equal positive impact for computing the vulnerability index. The model outputs the vulnerability of each of the state and union territory using TOPSIS method whose algorithm is shown in Figure 2. For validating our results, we compute the average of all reported crimes as an estimate WVI (E-WVI) for all Indian states and union territories. We compare results of our proposed algorithm with that of WCSI proposed by (1). The error computed for our model is much less than that of the other algorithm proving the effectiveness of our algorithm.

3. Experiments and Results

3.1 Crime Data Set construction

We collected the data from the website of National commission for women (NCW), (www.ncw.nic.in) the official website of Indian government. NCW maintains information about the number of cases registered at the commission by women for the crime they faced for each state and union territory. We collected the data for the last twenty-two years from 2001 to 2022. Total crimes over all the years for all the regions was calculated and a 36 X 9 table was created for 36 Indian states and union territories for 9 different types of crime against women. The dataset created is shown in Table 1.

	C1	C2	C3	C4	C5	C6	C7	C8	C9
AP	28	38	34	265	39	10	25	226	541
AR	3	1	3	13	3	0	0	3	7
AS	12	17	106	153	28	8	12	77	223
BR	200	207	2373	1482	448	91	284	2347	3325
CG	24	20	306	272	73	11	30	279	497
GA	3	3	10	40	6	0	3	15	127
GJ	26	39	276	356	67	13	19	261	488
HR	119	209	2800	2447	828	203	189	4164	4862
HP	14	18	135	166	18	6	14	145	307
J&K	12	19	105	119	10	4	9	126	296
JH	62	57	773	556	148	44	73	769	1147
KR	42	93	474	603	59	11	33	372	1361
KE	10	25	112	203	16	1	10	132	458
MP	155	255	2256	1935	447	105	243	2273	3183
MH	133	153	1141	1561	235	28	108	1301	3329
MN	2	0	5	6	4	1	0	10	11
MG	1	2	4	16	5	0	0	6	25
MZ	0	1	2	5	1	0	0	4	3
NL	0	0	0	5	7	0	0	2	2
OR	17	31	279	268	44	17	28	260	449
PB	37	68	827	688	116	23	32	780	1314
RJ	235	319	2927	2466	1168	212	306	4220	3762
SK	0	2	3	10	1	0	0	3	8
TN	68	56	453	696	75	19	51	815	1498
TL	30	40	304	298	59	6	17	253	633
TR	2	0	13	19	2	0	1	12	30
UP	1425	3830	34370	21473	7234	2185	1484	38174	54931
UK	87	114	1121	875	176	65	105	958	1666
WB	47	69	459	656	100	27	51	587	1723
A&N	2	2	3	28	0	0	0	5	16
CH	3	20	88	159	21	2	5	105	182
D&N	1	3	2	9	3	0	1	9	19
D&D	0	0	4	6	0	0	0	9	27
LK	0	0	1	2	0	0	0	1	4
DL	348	675	6164	5997	860	376	291	5902	12087
PC	2	3	24	48	5	2	3	35	54

AP:Andhra Pradesh; **AR**:Arunachal Pradesh; **AS**:Assam; **BR**:Bihar; **CG**:Chattisgarh; **GA**:Goa; **GJ**:Gujarat; **HR**:Haryana; **HP**:Himachal Pradesh; **J&K**:Jammu and Kashmir; **JH**:Jharkand; **KR**:Karnataka; **KE**:Kerala; **MP**:Madhya Pradesh; **MH**:Maharashtra; **MN**:Manipur; **MG**:Meghalaya; **MZ**:Mizoram; **NL**:Nagaland; **OR**:Orissa; **PB**:Punjab; **RJ**:Rajasthan; **SK**:Sikkim; **TN**:Tamil Nadu; **TL**:Telangana; **TR**:Tripura; **UP**:Uttar Pradesh; **UK**:Uttarakhand; **WB**:West Bengal; **A&N**:Andaman & Nicobar Islands; **CH**:Chandigarh; **D&**N:Dadra & Nagar Haveli; **D&D**:Daman & Diu; **LK**:Lakshwadeep; **DL**:Delhi; **PC**:Puducherery.

C1: Bigamy / Polygamy**; C2:** Divorce + Maintenance Claim + Women's right of custody of children**; C3:** Dowry Death + Dowry Harassment**; C4:** Harassment at workplace + Sexual harassment including sexual harassment at workplace+ outraging modesty of women**; C5:** Rape + Shelter & Rehabilitation of Victims**; C6:** Kidnapping / Abduction**; C7:** Murder**; C8:** Police Apathy against women**; C9:** Right to live with dignity

Table 1: Constructed Dataset

3.2 Computing WVI

Python code was developed to run the algorithm on the constructed dataset. The alternatives were chosen to be the Indian states and union territories. The crime incidents were used as factors to score the alternatives. Weights for each factor were calculated using mean weight method. All the factors were assumed to have a positive impact for computing the vulnerability index. The code for TOPSIS was run to output the scores/vulnerability index for each of the state and union territory as shown in Figure 3. The index computed will indicate the regions India where women are most susceptible to crime. The ranks of the regions based on the vulnerability or TOPSIS scores are shown in Table 2.

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

Table 2: WVI and Ranks of Indian states based on TOPSIS scores

Comparison of WCSI and WVI

For comparing the algorithm, we compared the ranks generated by WCSI and WVI for states and union territories of India. The Indian map showing the ranks of the states based on the vulnerability index as estimated by these algorithms is shown in Figure 3. The red-colored states are the most vulnerable states and the green ones are the safest states of India as far as security for women is concerned. The maps show that our algorithm WVI is close to the results which are reported by MHA. In Figure 4 we show the graph of ranks generated by both the algorithms. North eastern states like Tripura, Mizoram etc. have been shown to be more vulnerable by WCSI in contrast to WVI where they are the least vulnerable states of India. This result also matches with the results of NCRB. Figure 5 shows the error in computing the index. It is clearly shown in the figure that WVI has less error than WCSI thus proving that WVI is a better algorithm and closer to the results of MHA.

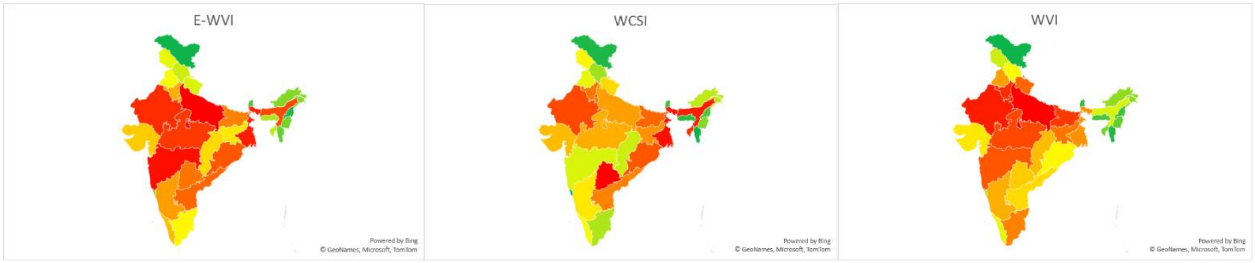

Fig 3: Maps showing Vulnerability of Indian States

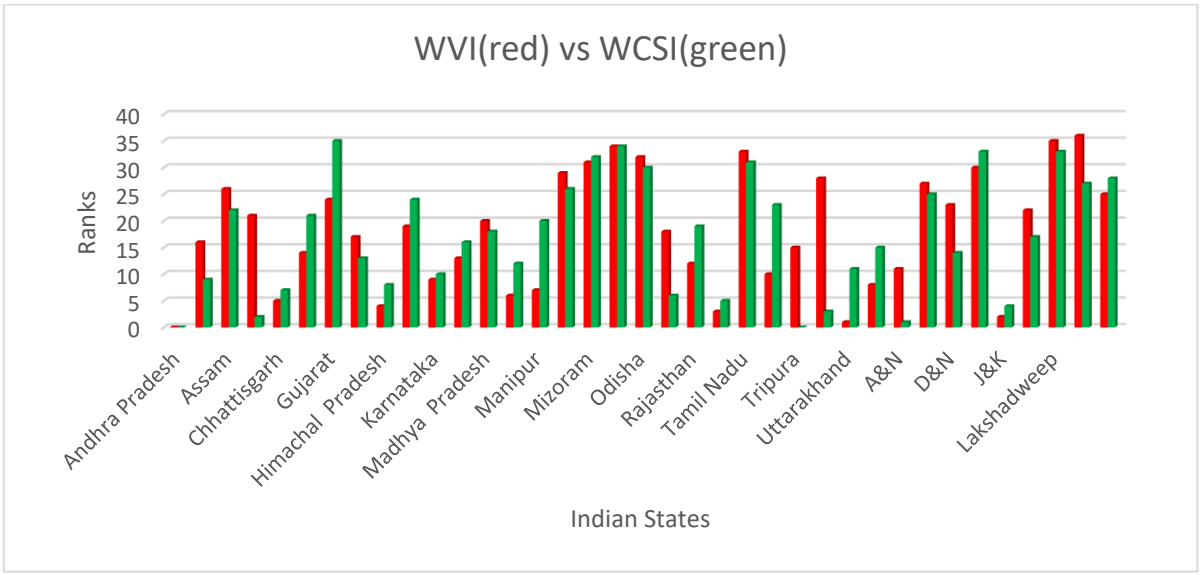

Fig 4: WCSI and WVI values for Indian states and union territories

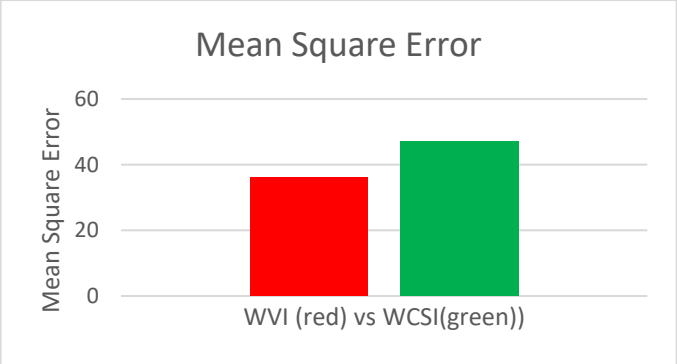

Fig 5: Comparison of WCSI and WVI

4. Conclusion

TOPSIS is a popular MCDM method applied for solving decision-making problems. It compares a set of alternatives based on available factors. This method is a mathematical model completely free from any human bias or knowledge. We find that the north eastern states like Mizoram, Nagaland, Sikkim, and Lakshadweep Island in southern India are the safest states for women in India having very low value of the index. On the other hand, Uttar Pradesh, Delhi, Haryana, Rajasthan, and Bihar shave very high index thus are regions where women are most susceptible to crime. These states require more attention from the authorities.

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