A Study of Multi Criteria Decision Analysis of Accident data for Indian states

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Abstract

Traffic accident is a great worry for traffic safety experts and city planners and authorities because it leads to serious and non-serious injuries, loss of human life and some material loss also. The major causes of traffic accidents has been due to interaction of person, motor vehicle, road and situation. It has been observed that in some states or cities or areas traffic accidents occur very frequently as compared to other states or places. By adopting Multi-criteria decision-making (MCDM) techniques, the ranking of various Indian states is carried out based on 11 evaluative criteria. By considering these evaluative criteria, like the fatal accidents, grievous injury accidents, minor injury accidents, severity of road accidents, eleven traffic safety criteria are adopted. In the first stage of the model, these eleven criteria has been given weights as per Entropy Weight Method (EWM). In the second phase, ten Indian States have been ranked based on these eleven criteria by adopting Technique of Order Preference Similarity to the Ideal Solution (TOPSIS) method. The attained results show which of the state is best ranked. Using these eleven criteria, the proposed model evaluates the road safety performance for a given set of 10 Indian states.

Keywords: traffic accidents, evaluative criteria, MCDM/MCDA, EWM, TOPSIS

1. Introduction

Due to India’s faster urbanization, increased growth of personalized vehicles, safety of commuters is the most significant challenges for India’s city planners and traffic safety experts. Each year road traffic accidents leads to death of more than 13 lakh people all over the world with a high percentage of fatalities occurring in the developing countries [1]. Also roughly two to five lakh people undergo non-fatal injuries. More than 50% of all the traffic fatalities comprises vulnerable road users like pedestrians, bicyclists and two-wheelers and their commuters [2].

Road traffic is a major factor towards economic growth by moving people, goods and raw materials. Although it leads to air pollution of large extent by effecting public health and also leading towards death and injury across the World. As per WHO, deaths due to accidents are the major cause of deaths and is the largest reason of deaths for children of the age group 5-14 and for adults in the age group 15-29. This leads to substantial financial losses to the effected persons, their relatives, and to the country as a whole.

In spite of the government’s assurance and determinations, road accidents is still the prominent reason of death, injuries and disabilities in the country. In India, every year road accidents kill nearly one and half lakh people. India leads the list of 199 countries in the number of road accident deaths. Thus, India’s share is roughly 10% of the
world’s accident related deaths. MORTH has formed a joint venture of IIT Delhi & DMITS to assess the socio-economic costs of road accidents. They have estimated that in 2018, roughly 1.5 lakh crores is the estimated socio-economic cost of road accidents. Thus accounting to 0.77% of the India’s GDP [3].

In India, during the calendar year 2019, 151,113 people died and 451,361 were injured in 449,002 accidents. Although the number of accidents reduced by 3.86% in 2019 as compared to 2018. But the accident related deaths reduced by only 0.20 % and the injuries due to accidents decreased by 3.86% [3]. The reason for this reduction may be attributed to implementation of The Motor Vehicle Act in States from 1st Sept 2019. This act focused on user safety on the roads and also high penalties for non-compliance of traffic rules. The enforcement of these laws is to be supplemented through electronic surveillance.

2. India’s Current Situation

2.1 India vs. World

As per World Road Statistics, 2018, India is at third position amongst 199 nations on the basis of total number of accidents. But, when we compare this data on the basis of per lakh of population, India's accidents rate is 36 which is quite less as compared to Japan which has 393 accidents per lakh of population and United States is at 684 accidents per lakh of population. On the basis of total deaths in accidents, India ranks the highest with more than 1.5 lakh deaths in 2019. Also, India has the third highest injured persons due to accident after USA and Japan. Although, India performs better (11th position) on the criteria of persons killed in accidents per lakh of population owing to second highest population of the world [4].

2.2 India vs Bharat

In 2019, rural areas contributed to around 60% of total accidents, more than 67% to persons killed in accidents and around 63% of persons injured in the accidents. Also, on comparing the last 4 years data, it can be inferred that share of rural areas is increasing with respect to all the three parameters [3].

2.3 Citywide Comparison

It is widely accepted fact that urban areas have higher number of road accidents owing to higher population density and congestion. As per [3], in 2019 metro cities contributed to little less than one-fifth of the total number of accidents and around 12% of accident deaths. In terms of injured persons, metro cities contributed little over 16% of the total 4.5 lakh injured persons in India. Also, it can be observed that over a period of last 4 years, metro cities showed an increase of around 2% in accidents related death, although the number of accidents decreased by 7% over the last 4 years (2015-19).

In term of number of accidents, Chennai has the highest rank for the last 2 years (2018 & 2019). But, due to better implementation of new MVA, it was able to reduce the number of accidents by nearly 10%. Surprisingly, in Jaipur there was an increase of more than 50% in number of accidents and more than 80% increase in accident related deaths. Inspite of having the highest accident related deaths in 2019, Delhi has reduced both number of accidents and accident related deaths in 2019 by around 14% over 2018 [3].

2.4 Accident scenario on National and State Highway

Tamilnadu, Uttar Pradesh and Karnataka were the top 3 states among the highest number of accidents on National Highways. In terms of accident related deaths on NH, Uttar Pradesh showed the highest figure of 8830 deaths.
Tamilnadu had the highest pedestrian related accidents on NH in 2019. While West Bengal had the highest pedestrian related deaths in accidents on NH. Similarly, Uttar Pradesh had the highest bicycle related accidents and deaths on NH in 2019. In 2019, Tamilnadu had the highest two wheeler related accidents on NH. While Uttar Pradesh had the highest two wheeler related deaths in accidents on NH.

On State Highways in 2019, Tamilnadu, Uttar Pradesh and Madhya Pradesh had the highest number of accidents. Also, Uttar Pradesh, Tamilnadu and Maharashtra were the top 3 states among the highest accident related deaths on State Highways. In 2019, Tamil Nadu had the highest persons with injuries due to accidents on SHs. In terms of fatal road accidents on SHs in 2019, Uttar Pradesh had the highest incidents [3].

3. Possible Cause of Accidents

Madhya Pradesh had the highest Hit and Run accidents and highest number of persons with minor injuries in 2019, while Maharashtra has the highest number of persons killed in Hit and Run accidents and highest number of persons with grievous injuries. Tamil Nadu has the highest number of accidents in residential areas and market or commercial areas, while highest number of persons killed in residential areas market or commercial areas were from Maharashtra and Uttar Pradesh respectively in 2019. Number of accidents and persons killed on straight roads were nearly 5 times as compared to curved roads which disapprove the belief that curved roads leads to more accidents. Accidents on bridges were also 3 times more than accidents due to pot holes which means that safety near and on bridges needs improvements. Accidents on ongoing road works or under construction were around 2.5% of the total number of accidents [3].

Number of accidents at Y-junctions, staggered junctions and 4-arm junctions were almost same, thus it can be inferred that all of it should be given equal importance for improving the safety aspects. It was also inferred from the data that police controlled intersection had more severity index compared to traffic light control intersections. Also stop sign and flashing light or blinder controlled intersections had almost same severity level [3].

Rainy and foggy or misty weather conditions had almost equal number of accidents. Also during sunny or clear weather conditions, number of accidents were 8-9 times the rainy weather conditions. This might be due to higher number of sunny days in the year in India. Vehicles having age between 10-15 years and above 15 years of age, had almost equal number of accidents. Also vehicles having age less than 5 years, had 3 times more than vehicles having age more than 15 years. But to draw any conclusion from this data, we have to see actually the number of vehicles of each type [3].

Normally loaded vehicles contributed to 60% of the total number of accidents, while over-loaded vehicles were responsible for only 8% of the total number of accidents. [5] did a study on the effect of several causal aspects on the bicycle which were involved in hit-and-run accidents using Louisiana accident data of six years. 80% of male pedestrians were killed in accidents. Similarly, 5 times more male bicyclist were killed in the road accidents. Number of male two-wheeler riders who were killed in the accidents were nearly 7 times the female two-wheeler riders. The reason might be due to higher number of male pedestrians, bicyclist and two-wheeler riders. Uttar Pradesh had the highest number of male two-wheeler riders killed in the accidents [3].

Nearly 7% males and 12% females who died in the accidents were of the age less than 18 years. Maximum percentage of males (26%) and females (22%) among different age-categories who died in the accidents were from...
the age category 25-35 years. Maximum number of male and female drivers who were killed in the accidents were from age category 25-35 years. Similarly, maximum number of male and female passengers who were killed in the accidents were from age category 25-35 years [3].

Roughly two-third of the accidents and number of persons killed in those accidents were due to over-speeding. Driving on the wrong side resulted into twice the number of accidents due to drunken driving. Use of mobile phones were the reasons for twice the number of accidents due to jumping the red light. Nearly 5% accidents were from drivers having learner’s driving license. It is broadly understood that two-wheeler users are comparatively more risky as compared to other highway users [6]. Two-wheeler riders are over and over again considered as atypical road users causing more accidents as they are more risk takers as compared to car drivers [7]. Number of Passengers (not wearing helmets) who were killed were nearly half the number of drivers (not wearing helmets) killed in the accidents. Nearly 20% more passengers (not wearing seat-belts) were killed in accidents as compared to drivers (not wearing helmets).

Nearly 40% of total number of accidents occurred in urban areas. Also nearly one-third of persons killed were from urban areas. Roughly 66% of the fatal accidents occurred in rural areas. Roughly 20% of the accidents occurred during 6-9 PM. Also surprisingly only 40% of the accidents occurred during night time which was also not as per widely known belief. Tamil Nadu (748) had the highest number of black spots among all the states [3].

4. Ranking of states based on Accident data

In this study, TOPSIS was adopted to rank the 10 Indian states based on their 11 factors (Table 1). Also, this analysis will be a tool to establish the performance of different Indian states. The entropy weight TOPSIS model is an enhancement over the customary TOPSIS model, and improves the value formula of the target object as well as both positive and negative ideal solutions. The weights are deliberated by the Entropy Weight Method (EWM) and then incorporated in the TOPSIS model to make the derived results objective and matching the real-life situations.

4.1 Entropy weight vector calculation

EWM is effective in accurately finding the weight by giving the relative significance of the recognized measures for Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) calculation [8]. This technique was first established from thermodynamics to information systems by Shannon [9]. The idea behind this entropy weight method is that large amount of information is required to calculate the index’s weight, which is comparable to the key feature of fixed weight methods [10].

In earlier studies, the criteria weight in TOPSIS method were calculated by the evolution of specialists. The results were quite subjective for calculating these weights in this method, which give a higher un-desirable effect on the projected outcome [11]. According to [12], to moderate the subjectivity, the entropy method should be adopted to estimate the authentic weights in this system, so as to avoid the subjectivity arising due to subjective factors. With use of this objective weighting process, researcher can remove the deficiency of this subjectivity in the weighting method (eq 6). Therefore, in this study, entropy weight method is adopted to decide the criteria weights.

Following steps are adopted in Shannon entropy weighting process:

Step 1: In this method, normalization is performed for the existing decision matrix. Suppose that the decision matrix
of A = (x_ij)_{m \times n}, m states and n evaluative criteria are existing. Therefore the decision matrix is normalized by Eq (1):

\[ \eta_j = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \]  

**Step 2:** Next step involves finding entropy of all the index:

\[ E_j = -\frac{1}{\ln m} \sum_{i=1}^{m} P_j \ln P_j , j = 1, ..., n \]  

**Step 3:** In this step, degree of deviation (D_j) for each criterion is found by following equation:

\[ D_j = 1 - E_j, j = 1, ..., n \]  

**Step 4:** Finally, we will calculate entropy weight of the evaluative criteria’s (Table 3).

\[ j_w = \frac{D_j}{\sum_{j=1}^{n} D_j} \]  

### 4.2 TOPSIS method

TOPSIS (Technique of Order Preference Similarity to the Ideal Solution) method was offered by [13], pertaining to [14]. TOPSIS technique depend on relative distance from best and anti-best solution. In TOPSIS method, relative distance value ranges from 0 to 1.

An upgraded Hierarchical Fuzzy TOPSIS method for evaluation of road safety for European countries was proposed by [15] in which 11 road safety performance indicators were adopted. [16] suggested Entropy TOPSIS-RSR technique in China wherein weight allocations were given based on the importance of 11 performance indicators.

The TOPSIS process involves following steps:

1. Calculate the normalized decision matrix (Table 2). The normalized value r_{ij} is calculated as

\[ r_{ij} = \frac{f_{ij}}{\sqrt{\sum_{j=1}^{n} f_{ij}^2}}, j = 1, ..., n; i = 1, ..., m \]  

2. Calculate the weighted normalized decision matrix.

\[ v_{ij} = w_i f_{ij}, j = 1, ..., n; i = 1, ..., m \]  

where v_{ij} is the weighted normalized value, where w_i is importance or weight of i^th attribute or criterion, and \( \sum_{i=1}^{m} w_i = 1 \)

3. Calculate the positive-ideal solution (A^+) and negative-ideal solution (A^-).

\[ A^+ = \{v_{jt} \cdots v_{jn}\} = \{(\max_j v_{ij} | i \in I'), (\min_j v_{ij} | i \in I'')\} \]

\[ A^- = \{v^- \cdots v^-\} = \{(\min_j v_{ij} | i \in I'), (\max_j v_{ij} | i \in I'')\} \]  

where I’ is related to beneficial criteria, and I’” is related to non-beneficial or cost criteria.

4. Find the separation distance. The departure of each substitute from the positive-ideal solution is given as

\[ D_j^* = \sqrt{\sum_{i=1}^{n} (v_{ij} - v_{ij}^*)^2}, j = 1, ..., n \]  

Likewise, the departure from the negative solution is provided by

\[ D_j^- = \sqrt{\sum_{i=1}^{n} (v_{ij} - v_{ij}^-)^2}, j = 1, ..., n \]  

5. Compute the C_j^* (relative closeness to the ideal solution). It is calculated as

\[ C_j^* = \frac{D_j^-}{D_j^- + D_j^*}, j = 1, ..., n \]  

6. Rank the preference order (Table 4).
5. Results and Discussion

The evaluative criteria data in the present paper for accident was collected from MoRTH Accident Data for 2019 to find out the ranking of the 10 Indian states by using the combined method involving both TOPSIS and Entropy.

To find the rank of the 10 Indian states, 10 criteria were deliberated (Table 1).

| States/UTs          | Length of NH 2019 | Length of SH 2017 | Fatal Accidents | Grievous Injury Accidents | Minor Injury Accidents | Non-Injury Accidents | Severity* of Road Accidents (Persons Killed/100 Accidents) | Total Number of Accidents/Lakh Population | Total Number of Road Accidents per 10,000 Vehicles | Total Number of Road Accidents per 10,000 Km of Roads (2018) |
|---------------------|-------------------|------------------|-----------------|---------------------------|------------------------|----------------------|----------------------------------------------------------------|------------------------------------------|---------------------------------------------|--------------------------------------------------|
| Andhra Pradesh      | 6529              | 6485             | 7,389           | 4,053                     | 9,235                  | 1,315                | 36.3                                                            | 24.3                                     | 18.3                                        | 1121.7                                           |
| Gujarat             | 6635              | 17201            | 6,726           | 5,826                     | 1,076                  | 3,343                | 27                                                              | 63.6                                     | 19.3                                        | 930.3                                            |
| Karnataka           | 7335              | 19578            | 10,060          | 9,768                     | 3,343                  | 27                   | 113.4                                                           | 30.8                                     | 1562.9                                      |
| Kerala              | 1782              | 4342             | 4,183           | 29,569                    | 6,043                  | 1,316                | 10.8                                                            | 117.5                                    | 136.5                                      |
| Madhya Pradesh      | 8773              | 10934            | 10,182          | 5,427                     | 4,467                  | 22.2                 | 62.5                                                            | 38.4                                     | 1412.1                                      |
| Maharashtra         | 1757              | 39080            | 11,787          | 5,473                     | 3,468                  | 38.8                 | 26.5                                                            | 9.3                                      | 570.1                                       |
| Rajasthan           | 9999              | 15188            | 9,471           | 4,226                     | 8,966                  | 817                  | 45                                                              | 31                                       | 13.3                                        | 693.8                                            |
| Tamil Nadu          | 6742              | 11752            | 9,813           | 4,190                     | 7,592                  | 18.4                 | 81.4                                                            | 19                                       | 2367.3                                      |
| Telangana           | 3796              | 2731             | 6,472           | 2,190                     | 10,792                 | 2,116                | 61.6                                                            | 17.8                                     | 1735.8                                      |
| Uttar Pradesh       | 11737             | 7147             | 19,731          | 13,651                    | 7,739                  | 1451                 | 18.7                                                            | 13                                       | 975.6                                       |

**Table 1: List of states and Accident evaluative criteria**

| States/UTs          | Length of NH 2019 | Length of SH 2017 | Fatal Accidents | Grievous Injury Accidents | Minor Injury Accidents | Non-Injury Accidents | Severity* of Road Accidents (Persons Killed/100 Accidents) | Total Number of Accidents/Lakh Population | Total Number of Road Accidents per 10,000 Vehicles | Total Number of Road Accidents per 10,000 Km of Roads (2018) |
|---------------------|-------------------|------------------|-----------------|---------------------------|------------------------|----------------------|----------------------------------------------------------------|------------------------------------------|---------------------------------------------|--------------------------------------------------|
| Andhra Pradesh      | 0.22615           | 0.12238          | 0.22501         | 0.10033                   | 0.16099                | 0.32754              | 0.13078                                                        | 0.27949                                   | 0.26207                                      | 0.21735                                         |
| Gujarat             | 0.22982           | 0.32461          | 0.20482         | 0.14422                   | 0.05958                | 0.14430              | 0.39161                                                         | 0.14154                                   | 0.10386                                      | 0.32992                                         |
| Karnataka           | 0.25407           | 0.36946          | 0.30635         | 0.43288                   | 0.17028                | 0.44832              | 0.24363                                                         | 0.34228                                   | 0.29477                                      | 0.27487                                         |
| Kerala              | 0.06172           | 0.08194          | 0.12738         | 0.73196                   | 0.10534                | 0.17649              | 0.09745                                                         | 0.61029                                   | 0.47041                                      | 0.36515                                         |
| Madhya Pradesh      | 0.30387           | 0.20634          | 0.31007         | 0.13434                   | 0.53331                | 0.59906              | 0.20332                                                         | 0.33636                                   | 0.58648                                      | 0.32992                                         |
| Maharashtra         | 0.61506           | 0.73599          | 0.35894         | 0.30193                   | 0.09541                | 0.46509              | 0.35010                                                         | 0.14262                                   | 0.14204                                      | 0.13320                                         |
| Rajasthan           | 0.34634           | 0.28662          | 0.28842         | 0.10461                   | 0.15630                | 0.10957              | 0.40604                                                         | 0.16683                                   | 0.20313                                      | 0.16210                                         |
| Tamil Nadu          | 0.23353           | 0.22178          | 0.29883         | 0.09335                   | 0.74759                | 0.10179              | 0.16603                                                         | 0.43808                                   | 0.29018                                      | 0.55309                                         |

**Table 2: Normalized Decision Matrix**
Table 3: Weights as per Entropy Method

| States/UTs         | Length of NH 2019 | Length of SH 2017 | Fatal Accidents | Grievous Injury Accidents | Minor Injury Accidents | Non-Injury Accidents | Severity* of Road Accidents (Persons Killed/100 Accidents) | Total Number of Accidents/Lakh Population | Total Number of Road Accidents per 10,000 Vehicles | Total Number of Road Accidents per 10,000 Km of Roads (2018) |
|-------------------|------------------|------------------|----------------|--------------------------|------------------------|----------------------|-----------------------------------------------------------|---------------------------------------------|-----------------------------------------------|--------------------------------------------------------|
| Telangana         | 0.13148          | 0.05154          | 0.19709        | 0.05421                  | 0.18813                | 0.28377              | 0.29145                                                   | 0.33152                                      | 0.27186                                      | 0.40555                                                |
| Uttar Pradesh     | 0.40654          | 0.13487          | 0.60086        | 0.33792                  | 0.13491                | 0.19459              | 0.48003                                                   | 0.10064                                      | 0.19855                                      | 0.22794                                                |

Table 4: Final Ranking of States based on Accident related Criteria

| States/UTs         | Sqrt (SUM) Di+  | Sqrt (SUM) Di-  | Relative Closeness | Rank |
|-------------------|----------------|----------------|-------------------|------|
| Andhra Pradesh    | 0.197371977    | 0.0331537      | 0.143817819       | 10   |
| Gujarat           | 0.19615504     | 0.0475463      | 0.195100681       | 8    |
| Karnataka         | 0.142643399    | 0.09737682     | 0.405702578       | 5    |
| Kerala            | 0.169756493    | 0.13308613     | 0.439456401       | 4    |
| Madhya Pradesh    | 0.143571118    | 0.11676208     | 0.448510141       | 2    |
| Maharashtra       | 0.15780506     | 0.1244341      | 0.440881772       | 3    |
| Rajasthan         | 0.188208786    | 0.04947063     | 0.20814015        | 7    |
| Tamil Nadu        | 0.152040845    | 0.14031911     | 0.479953241       | 1    |
| Telangana         | 0.199820848    | 0.04303541     | 0.177205258       | 9    |
| Uttar Pradesh     | 0.177317051    | 0.06796398     | 0.277086177       | 6    |

Based on the above method, the states are being ranked as per the table. Tamil Nadu has first rank due to high number of accidents, high number of persons killed in accidents, etc.

6. Measures recommended for reducing the Accidents

As per the Stockholm declaration to reduce the deaths from road accidents by 50% by end of this decade, India is doing efforts by introducing the new MVA. It is inferred that road accidents are due to various causes which needs multi-stage actions to reduce the road accidents by intensive efforts by different agencies of the government.

In order to increase the safety road users, long-term preparation. Efforts should be made to control the number
of road fatalities can and reduce the chance of crashes by adopting 3E’s – Engineering, Education and Enforcement. Authorities and government agencies should develop such framework so as to decrease exposure to danger by adopting favourable transportation and land-use strategies; modelling the road system to prevent and reduce the road injury, improving safe visibility for all road users, encouraging crash-shielding automobile design, setting up and safeguarding acquiescence towards road safety guidelines, also developing and delivering post-accident care.

Following measures should be adopted to reduce the chances of accidents and deaths, injuries:

- Enforcement authorities should try to adopt policies so as to enforce speed limits. This can be done by installing camera surveillance, use of interceptor vehicles, etc.
- Drivers should be fully informed about road condition, road severity information, speed limits, etc.
- For drivers of buses, trucks, lorries, etc. camps for vision testing should be organized [3].
- Concerned authorities should identify the accident black spots and try to rectify them. Drivers should be informed well in advance if he is approaching any accident prone area.
- Periodic and regular Road Safety Audits should be conducted to as to maintain the safety aspect on NHs and SHs. RSA at different stages of the project is also suggested by MORTH. This will help in long term in order to reduce the accident rates.
- In order to make networks safer for 2-wheelers in India, MoRTH has instructed automobile manufacturers to have head light as ‘always ON’ [3].
- Implementation of crash test for all types of LMVs.
- For LMVs, many safety norms have been made mandatory like fitting driver air bags (front seat in cars to be mandatory from April 2021), seatbelt reminder for driver and co-driver, rear parking sensors and speed alert system.
- Severe penalties to improve safety.
- Confiscation and suspension of driver’s license for offences like over speeding [1], unsafe driving, driving under influence of alcohol/drug, not wearing seat-belts and helmets [1], use of mobiles while driving, etc.
- Developing strategies to encourage usage of helmets by launching promotional events, distribution of helmets to targeted groups and offenders.
- Training programs to children for bicycle usage, and on car driving behavior for youngsters.

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