CHAPTER 6
EXPLORING NEGATIVE IMPACTS OF RURAL ROADS USING FUZZY MULTICRITERIA APPROACH

6.1 Introduction

This chapter deals with investigation and assessment of various factors contributing to negative impacts (degradation of both physical and social environment) of rural road construction. The study attempts to explore the negative impacts of rural road construction on the target population and identifies the most negatively impacted attributes among the six chosen attributes viz., status of road accidents, status of transmissible diseases, status of ill habits/behavior, status of safety and security, status of air quality, and status of noise pollution. These attributes represent both physical and social environment. The study presented in this chapter provides groundwork for the concerned decision makers to focus on assessing and mitigating the impacts (negative) induced by the construction of rural (PMGSY) roads. Thus, helping them to achieve their intended goal of sustainable rural development.

6.1.1 Negative impacts of rural roads

Rural roads have been extensively considered as the significant instrument in poverty alleviation of rural areas. They are the key to raise the living standard of the rural population. Improved rural roads assist in generating new linkages to nearby markets by reducing travel time and lowering travel cost (Van de Walle, 2009). Moreover, improved rural road infrastructure facilitates access to social services (e.g. health services and education facility) thereby enhancing social outputs. They play a vital role in generating employment opportunities for rural communities through a combination of integrated road networks (Gachassin et al., 2010; Rand, 2011). Rural roads significantly assist in the distribution of services to the rural inhabitants (Aderamo and Magaji, 2010) and provide numerous avenues of income opportunities (Kanuganti et al., 2017). They influence income diversification process by paving a way to non-farm employments opportunities for rural inhabitants (Abur et al., 2015).

Improvised rural roads assist and provide access to new technology and encourage rural inhabitants to involve into prolific income earning activities (Binswanger et al., 1993; Aggarwal, 2018). The ehancement in rural roads reduces the transportation cost of agricultural goods, thereby increasing the earnings of rural inhabiatnts (Tunde and Adeniyi, 2012). Rural roads also assist rural inhabitants to withstand against economic shocks (Burgess and Donaldson, 2012) and significantly influence the social status of rural inhabitants. Studies have also accounted that transport infrastructure paves access to the markets for the agricultural produce of the rural community, and have assisted in increasing their productivity of agricultural goods as expained earlier (Asomani-Boateng et al., 2015). However, along with economic benefits, rural roads also induce multidimensional positive impacts. Some of them are access to services such as education and health facility. An improvised rural road enhances the access to educational institutes in terms of reduction in travel distance and travel time required to reach schools and other educational facilities. It encourages school enrollment among the target population due to reduction in effective distance of travel (Muralidharan and Prakash, 2017), thereby nullifying the provision of new schools.

There are number of evidences, which demonstrate that the implementation of rural road development projects helps significantly to increase the percentage of school going children (Khandker et al., 2009). This also holds true in the case of access to a health facility. Provision of rural roads improves potential access to the health care facility (Rand, 2011; Wondemu and Weiss, 2012; Kanuganti et al., 2016). With improved road conditions, the rural inhabitants can get access to a health facility at first call especially rural women. Though, there are positive outcomes of the construction of rural roads, there are also possibilities that they may have some negative impacts on the biophysical environment and target population. It may be in terms of consequences, viz., disturbance of the natural environment, soil erosion, increase in air pollution, etc. When the condition of rural roads is improved it can potentially attracts more traffic, which leads to increase in number of accidents as well as increases in localized air pollution (Desapriya et al., 2012). They may also generate competitiveness among rural inhabitants, thereby creating regional monopolies which cause some of the local farmers to lose their markets.

Contemporary literature addresses only about the impacts of rural road construction on the biophysical environment. Rural road construction may negatively affect the natural habitats of indigenous animal and plant species; it may have significant negative impact on the physical features at landscape levels (Forman and Alexander, 1998; Trombulak and Frissel, 2000). Due to road improvement, the volume of traffic commuting on these roads is likely to increase, thereby creating noise and air pollution and distrupting the sensitive wildlife and ecological balance. Moreover, this may cause emission of contaminants (e.g., engine oils, fuels, carbondioxide, and other chemicals) and degrade the effectiveness of the habitat (Luce and Wemple, 2001; Madej, 2001). Other adverse effects of rural road construction are deforestation (i.e., through conversion of land or increase in harvesting of natural (environmental) resources to supply urban markets), fragmentation of landscapes, increase in occurrence of landslides, spread of hostile species which may bring diseases to wildlife and fauna, and depletion of wildlife through subsistence hunting (Daigle, 2010).

Rural roads have also been considered as ideal passageways for transmission of diseases and declining in the health of the local population through possible cause of contamination of local water supply (Tsunokawa and Hoban, 1997). Increased mobility through roads can encourage transmission of communicable diseases which includes sexualy transmitted diseases (STDs) to a larger extent (Mashiri, 2004; Ferguson and Morris, 2006). A study by Feldacker et al. (2011) in rural Malawai, showed that the status of odds of STDs like human immuno deficiency virus (HIV) among both the genders (men and women) has increased considerably. Apart from these adverse impacts of rural roads there are likely increase in the safety concern of the target population. As in case of developing countries, rural roads consists of mixed traffic. It consists of three components, viz., pedestrian, non-motorised, and motorised traffic. The motorised traffic is considerably less compared to other two components. However, due to improvement in road conditions there are possibilities of increase in motor vehicles making pedestrian and non-motorised traffic vulnerable with the risk of being injured in an accident (Desapriya et al., 2012). From the literature discussed above it is understood that most of the studies have addressed only adverse impacts of road construction on biophysical environment. Therefore, this creates a need to explore and develop a model which is able to amalgamate impacts of rural road constrcution on both physical and social environment into single model using comprehensive methods.

According to the contemporary literature, approaches commonly used for assessing the impacts (positive especially) of rural road construction are experimental designs, quasi-experimental designs, qualitative approaches, and multi-criteria decision-making approach. However, the experimental design (randomization technique) is considered to be the most suitable technique for impact evaluation. The main viewpoint of this technique is to assess the effectiveness of the development program by comparing expected impacts of the target population with that of the control population. This is achieved by selecting the target population and control population randomly. But it would be erroneous sometimes to rely completely on such random selection thus resulting into incomplete evaluation (Barnow and King, 2000). Nonetheless, in the case of quasi-experimental and qualitative approaches, they suffer from biasness issues (Suresh, 2011). Considering these facts multi-criteria decision making (MCDM) approach is found to be superlative to assess and identify the parameters which are likely to contribute to the negative impacts of road construction. The approach considers various course of action, which are difficult to be assessed by employing single and simple dimensions (Chen et al., 2015). In the MCDM technique, the attributes contributing to the problem are identified and are ranked based on their relative significance.

The literature suggests various MCDM techniques which can be employed to assess the impacts of rural road construction. Among these techniques mainly employed are analytical hierarchy process (AHP), Elimination Et Choix Traduisant la Realite (ELECTRE III) and Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) (Wagale et al., 2019). These techniques focus on identifying as well as ranking of the factors which have been impacted by the road construction. Among all the MCDM techniques, AHP has been used many times for assessing the impacts, but the technique suffers from some weakness which is required to be addressed. For example, it suffers from the problem of non-uniqueness in results (i.e., inconsistency induce in the assessment process due pair-wise comparison, and there may be possibility in reversal in the order of ranks of the attributes/factors considered for the assessment, when any attribute is eliminated or added) (Wang et al., 2009). Furthermore, it requires a huge amount of computational data and is based on probability and possibility measures of assessment. Therefore, this may lead to incorrect interpretation of the results. Though, the MCDM approaches have been accepted as an effective tool in dealing with impact assessment studies, still they have certain shortcomings (i.e., incapable of accounting imprecision and vagueness in the data) associated with them, which calls for employing fuzzy integrated MCDM approaches.

But so far, no study has been reported where the application of fuzzy MCDM approaches have been employed to assess the negative impacts of rural road construction. The methods like fuzzy

TOPSIS, fuzzy Delphi method, and improved fuzzy weighted average method (IFWA) form a strong basis as they can overcome the limitations of conventional MCDM techniques with ease as well as are cost and time effective. Therefore, considering these facts along with previous research and literature on impact assessment, a novel coherent evaluation methdology is proposed in this chapter. It is based on fuzzy TOPSIS and improved fuzzy weighted average methods. From practical applicability viewpoint the proposed model can handle complexities by exploiting necessary information perceived and comprehended from the stakeholders and will help concerned decision makers to initiate necessary corrective actions to mitigate the substantial negative impacts.

The chapter is structured as follows: Section 6.1 introduces the study and its need. Section 6.2 elaborates the methodology followed with a brief description of the study area and data collection. Section 6.3 briefly illustrates the procedure of the proposed methods. Section 6.4 then presents the practicality of the proposed model through results and discussions for the case study employed which then followed by the summary.

6.2 Methodology

The present study proposes a novel model to assess the attributes contributing to the negative impacts of road construction in context with rural habitations. The steps followed in the study are outlined below:

Step-1: It deals with the identification and selection of the rural road stretches. In the case of present study rural roads belonging to six different divisional blocks of Jhunjhunu district of Rajasthan state, India have been identified, which are constructed under Pradhan Mantri Gram Sadak Yojana (PMGSY) program. The program is meant to connect small villages and habitations to nearest market place or to the major road connectivities. It is then followed by assimilation of attributes and features that contribute to negative impacts concerning rural road construction. These are identified based on the literature reviewed. They are finally attained by taking the opinion of the experts belonging to the research institutes and working in the field of rural development.

Step-2: It follows a preliminary field survey through site inspection which is then followed by a focus surveys. Data collection through focus group surveys has been carried out from March to April 2018 for the selected PMGSY road stretches. A total of 27 focus group discussions have been performed. The data pertaining to both the physical and social environment have been collected.

Step-3: It accomplishes assessment of the data collected for the attributes by employing the proposed model, which helps in the identification of the attributes based on their relative significance. The steps followed for the study are depicted in Fig. 6.1.

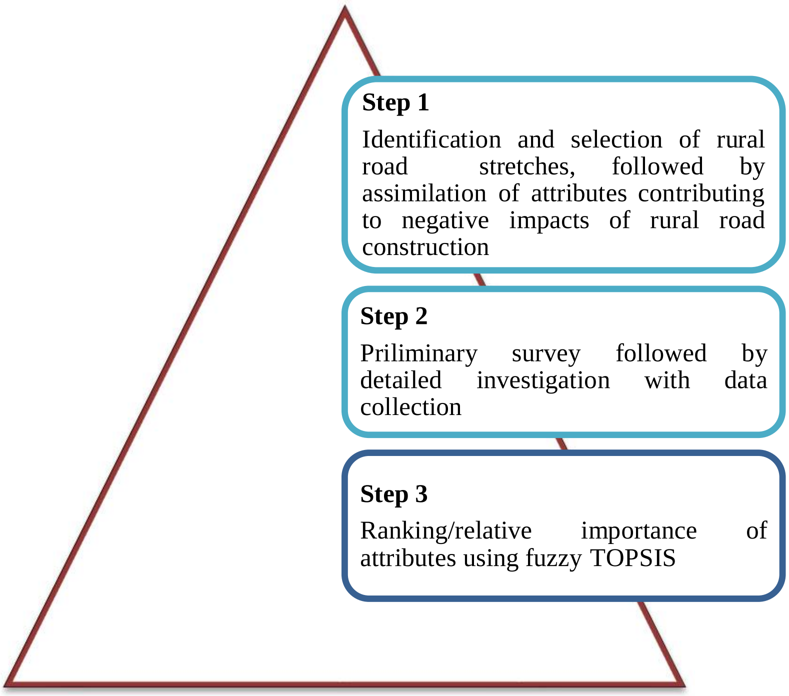

Fig. 6.1 Steps followed in ranking the attributes

6.2.1 Case study and data collection

Data for the study has been collected through focus group discussions during the months of March to April 2018 from 27 connectivities, which are distributed in six different divisional blocks of Jhunjhunu district of Rajasthan state of India as explained earlier in section 4.3.4 of chapter 4. To have proper comprehension about the attributes and features to be selected for the study, available literature (Tsunokawa and Hoban, 1997) has been reviewed which is then followed by discussions with experts. Furthermore, a preliminary survey and discussions with village representatives has also been performed to identify significant attributes and features. Thus, six attributes have been finalized which contribute to negative impacts of rural road construction. The attributes considered are, viz., status of road accidents, status of transmissible diseases, status of ill habits/behaviour, status of safety and security, status of air quality, and status of noise pollution. Table 6.1 shows the attributes employed for the study.

Data has been collected in a qualitative way to assess the significance of the attribute/feature using the questionnaire as shown in Appendix III. Moreover, to prevent error in the data an attempt has been made by facilitating feedback from the participants at the end of focus group discussion. Fig. 6.2 represents the study area considered for the research.

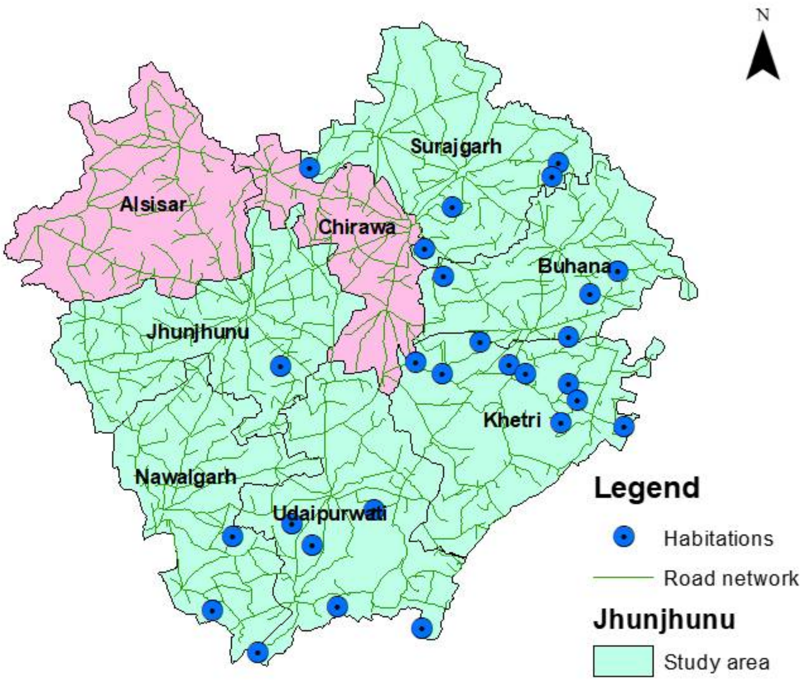

Fig. 6.2 Geographical location of Habitations in Jhunjhunu District

Table 6.1 Attributes and features contributing to negative impacts of rural road construction

Attribute	Symbol	Feature
Status of behavior/habits	S_B	Increased consumption of alcohol, use of drugs, involvement in illegal activities.
Status of road accidents	S_A	Speeding of vehicles, drinking and driving, no sign boards, faulty road geometrics.
Status of safety and security	S_{SS}	Thefts and burglaries.
Status of transmissible diseases	S_{TD}	Increased vulnerability to communicable diseases like STDs.
Status of Noise pollution	S_{NP}	Increase in vehicular traffic, easy access of loudspeakers
Status of air quality (dust particles)	S_{AQ}	Increase in vehicular traffic

6.3 Data analysis

Evaluation of attributes contributing to the negative impacts based on their relative significance helps concerned decision makers, to identify the potential aspects which are undesirable from the point of view of rural development. It assists them in implementing essential plans which help in mitigating those undesirable effects of road construction and enhancing the conditions of rural households. Assessment of these attributes is a multi-criteria decision-making problem. In this study fuzzy TOPSIS and improved fuzzy weighted average method (IFWA) have been employed to assess the data, the techniques have been chosen because crisp data are inadequate in modeling real-life problems. Moreover, data collected are based upon human perception which are often imprecise and vague and cannot be assessed using precise numerical value (Bellman and Zadeh, 1970; Chen, 2000; Singh et al., 2019).

6.3.1 Application of fuzzy TOPSIS approach

Assessing negative impacts of rural road construction through focus group discussion involves participants as decision-makers, the data collected usually is in the form of linguistic judgments rather than crisp values. This helps enumerators to capture the data in a fuzzy form. A few number of studies have introduced the concept of fuzzy theory to improve such MCDM problems. Among such fuzzy MCDM methods, fuzzy TOPSIS is one such technique which considers the uncertainty of human cognition and vague judgments (Chen et al., 2015; Kahraman et al., 2007). The fuzzy TOPSIS approach considers the shortcomings of earlier proposed methods effectively. It has ability to overcome the disadvantages of pairwise comparison between criteria/sub-criteria and alternatives to be evaluated (Liang and Meng, 2019). Considering this fact present study employs fuzzy TOPSIS (see Fig. 6.3) approach proposed by Chen, the systematic step-wise procedure followed to evaluate the relative significance of the attributes/features has been illustrated below.

Moreover, the hierarchy structure of the attributes with respect to criteria considered for the study is shown in Fig. 6.4.

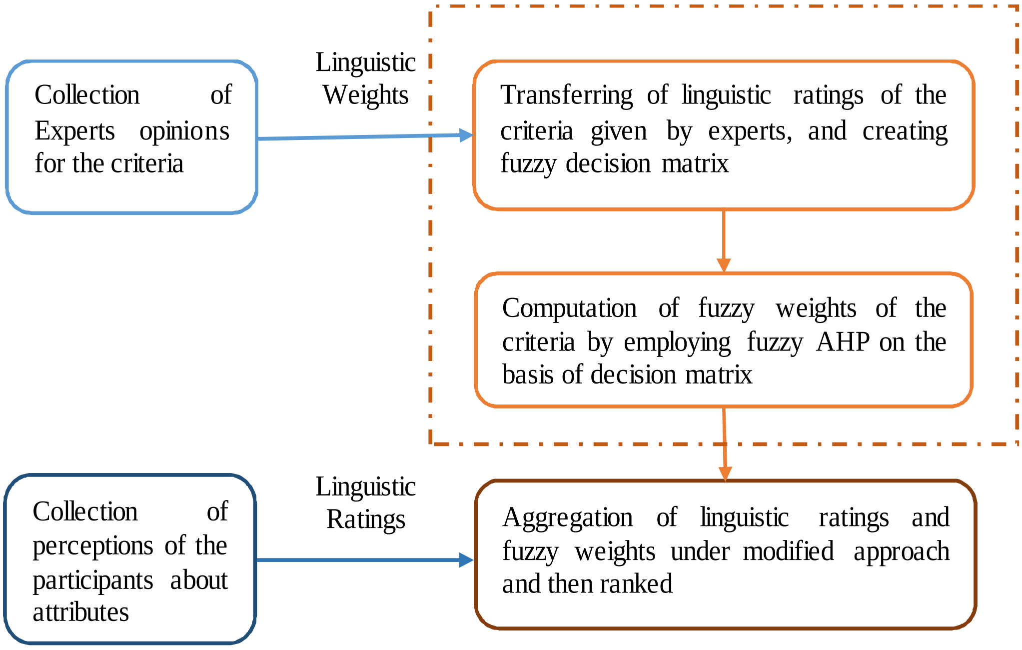

Fig. 6.3 TOPSIS framework

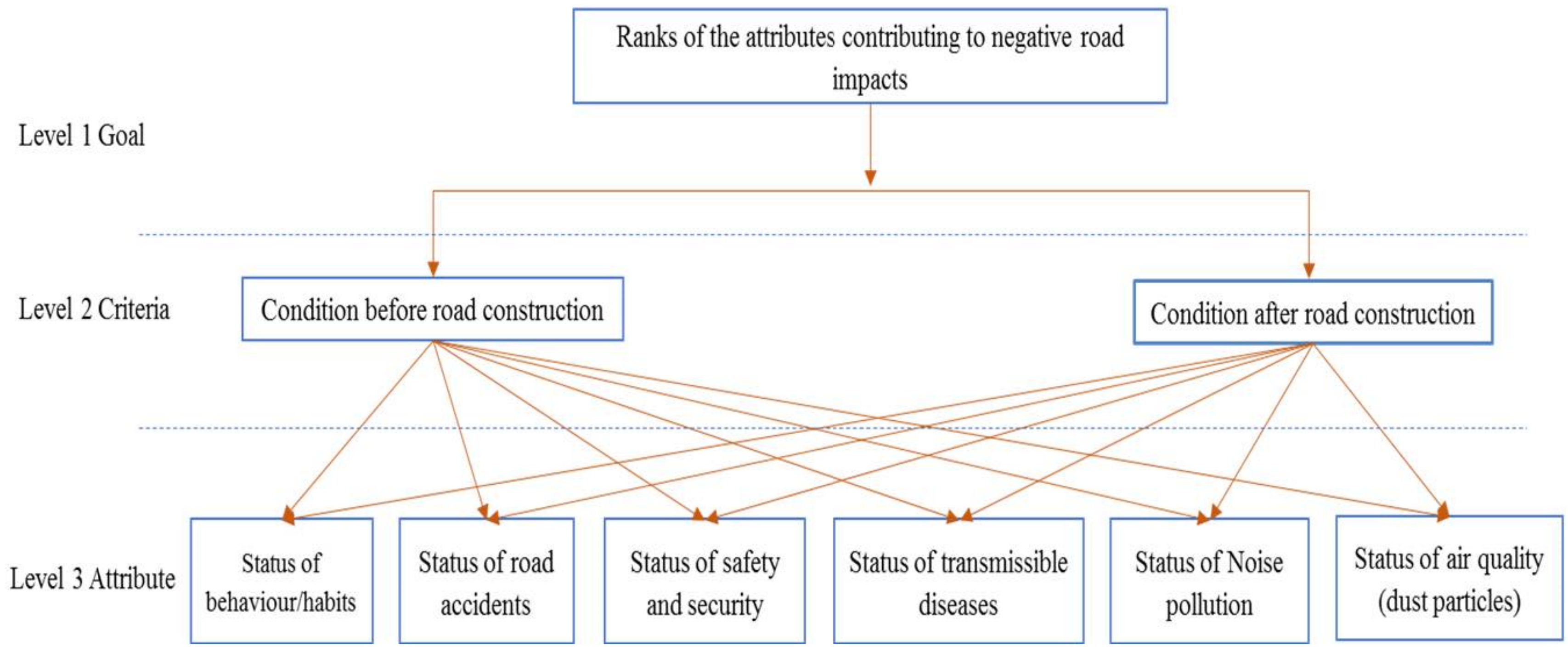

Fig. 6.4 Hierarchy structure for evaluating the negative impacts of rural road construction

The algorithm of fuzzy TOPSIS is as enlisted stepwise below:

Step-1: In this step, the important attributes contributing to the negative impacts of road construction are identified. They are assessed with respect to condition before and after the construction of rural (PMGSY) roads. Further, the ratings of the attribute are transformed from linguistic scale to fuzzy number to obtain fuzzy judgment matrix. In this study triangular fuzzy number has been employed. Fig. 6.5 below depicts the fuzzy membership scale employed in the study to illustrate the ratings of the attribute. Table 6.2 below elucidates the linguistic variables adopted for the study. Moreover, this fuzzy scale has been decided upon opinions obtained from the experts working in the field of rural development and research institutes. Table 6.3 summarizes linguistic rating given by the experts to the criteria.

Table 6.2 Fuzzy numbers defining linguistic ratings for the attributes

Linguistic ratings	Triangular fuzzy number
Very insignificant (VIS)	(0.0, 0.1, 0.2)
Insignificant (IS)	(0.1, 0.3, 0.5)
Moderately significant (MS)	(0.3, 0.5, 0.7)
Significant (S)	(0.5, 0.7, 0.9)
Very significant (VS)	(0.7, 0.9, 1.0)

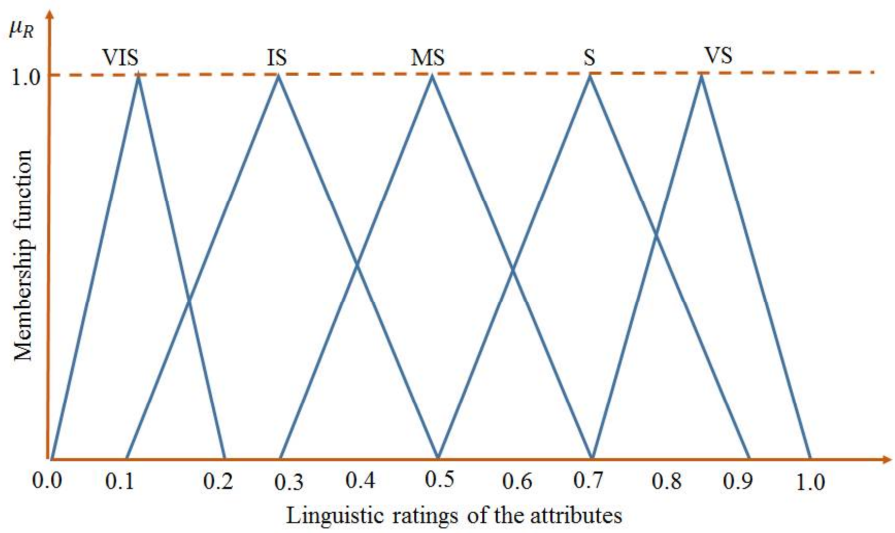

Fig. 6.5 Membership scale for attribute ratings

Table 6.3 Linguistic ratings of the criteria given by the experts

Criteria	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
Condition before road construction	VS	MS	MS	S	MS
Condition after road construction	S	S	S	VS	S

Step-2: This step follows the assessment of comparative importance weights. In this study two criteria with respect to the negative aspects, viz., condition before road construction and condition after road construction have been considered. The study employs a fuzzy analytical hierarchy process (FAHP) to assess the comparative importance weight. For example, the linguistic rating for the condition before road construction criteria given by each of five expert are (S, S, S, VS, S). Then the geometric mean fuzzy comparison value obtained for this criteria is ($\widetilde{r_1}$ = 0.61, 0.68, 0.79). Further, the fuzzy weight ($\widetilde{w_2}$ = 0.25, 0.32, 0.42) for this criteria is obtained using equation (6.1). And, finally the crisp weight is obtained using geometric mean integration representation (GMIR) as 0.324. Table 6.4 shows the weights obtained for "Condition before road construction" and "Condition after road construction" criteria.

$$\widetilde{w_2} = (\widetilde{r_1} \otimes \widetilde{r_2})^{-1} \tag{6.1}$$

where $\tilde{a}_{11}, \tilde{a}_{12}$ are the fuzzy comparison values obtained based on linguistic ratings of the experts.

Table 6.4 Weights of the criteria

Criteria	Weight
Condition before road construction	0.324
Condition after road construction	0.639

Step 3: In this step, mean fuzzy dominance rating of attributes/ features with respect to criteria is evaluated. Let, $D_{ic}^f = (C_{ic}^f, A_{ic}^f, B_{ic}^f)$ is the fuzzy dominance rating of the i^{th} attribute in reference to the c^{th} subjective criteria, evaluated by the f^{th} focus group, where (i = 1, …., m; c = 1, …, p; f = 1, …, n). The mean fuzzy dominance rating of the i^{th} attribute with reference to the c^{th} subjective aspect evaluated by the f^{th} focus-group is evaluated as given below in equation (6.2):

$$\left[\frac{\sum_{f=1}^{n} C_{ic}^{f}}{n}, \frac{\sum_{f=1}^{n} A_{ic}^{f}}{n}, \frac{\sum_{f=1}^{n} B_{ic}^{f}}{n}\right] \quad (6.2)$$

Step 4: This step follows computation of ideal and nadir solutions. The ideal and nadir solutions are assessed on the basis of comparative proximity. They are observed as the distance of attributes i with respect to the ideal (nadir) solutions (Liang and Meng, 2019). If the attributes are positive in nature, the standardized fuzzy dominance rating D_{ij} (max) of the i^{th} sub-criteria with respect to aspect j is evaluated as shown in equation (6.3), where Δ_j = max (B_{ij}).

$$D_{ij} = \left(l_{ij}, m_{ij}, k_{ij}\right) = \left[\frac{C_{ij}}{\Delta_j}, \frac{A_{ij}}{\Delta_j}, \frac{B_{ij}}{\Delta_j}\right] \quad (6.3)$$

and if the attribute which adds up negative value is defined as shown in equation. (6.4)

$$D_{ij} = \left(\frac{\gamma_{ij}}{C_{ij}}, \frac{\gamma_{ij}}{A_{ij}}, \frac{\gamma_{ij}}{B_{ij}}\right) \quad (6.4)$$

where γ_j is min (B_{ij}).

Therefore, the fuzzy ideal and nadir solutions are determined by employing the representation vale R(d_{ij}) and are finally are defined as:

Fuzzy ideal solution (I) = ($D_1^+, D_2^+, \ldots, D_j^+, \ldots, D_c$) and

Fuzzy nadir solution (N) = ($D_1^-, D_2^-, \ldots, D_j^-, \ldots, D_c^-$), respectively.

Table 6.5 below shows the fuzzy ideal and nadir solutions obtained for attribute with respect to criteria.

Table 6.5 Fuzzy ideal and nadir solutions of attribute with respect to criteria

Attribute	Condition before road construction			Condition after road construction		
Status of behavior/habits	0.150	0.207	0.330	0.210	0.283	0.474
Status of road accidents	0.161	0.204	0.309	0.200	0.262	0.411
Status of safety and security	0.160	0.223	0.366	0.210	0.291	0.486

Status of transmissible diseases	0.263	0.406	0.958	0.310	0.468	1.000
Status of noise pollution	0.182	0.262	0.479	0.220	0.321	0.578
Status of air quality (dust particles)	0.244	0.375	0.848	0.260	0.381	0.711

Step 5: In this step the distance of attributes is computed with respect to the fuzzy ideal (I) and fuzzy nadir (N) solutions by employing equation (6.5) and equation (6.6) as shown below. Table 6.6 shows the distance of attribute with respect to IS and NS respectively.

$$d_i^+ = \sqrt{\sum_{j=1}^{c}\left[(\beta_j)^2 \times \left(\alpha_M \times (D_j^+, D_{ij})\right)^2\right]} \quad (6.5)$$

$$d_i^- = \sqrt{\sum_{j=1}^{c}\left[(\beta_j)^2 \times \left(\alpha_M \times (D_j^-, D_{ij})\right)^2\right]} \quad (6.6)$$

where

d_i^+ and d_i^- represent the distance of attribute from I and N.

α_M is the integrated weight of the attribute.

β_j is the distance between two fuzzy numbers.

Table 6.6 Distance of the attributes with respect to IS and NS

Attribute	d_i^+	d_i^-
Status of behavior/habits	0.441	0.541
Status of road accidents	0.439	0.544
Status of safety and security	0.448	0.537
Status of transmissible diseases	0.563	0.518
Status of noise pollution	0.467	0.527
Status of air quality (dust particles)	0.534	0.515

Step 6: This step follows the computation of comparative estimate of attributes with respect to the ideal solution and raking them accordingly. Table 6.7 below depicts the comparative estimate of

the attributes and their ranks. The comparative estimate (CE^*) of the attribute with respect to the fuzzy ideal solution is evaluated using equation (6.7).

$$CE^* = \frac{d_i^-}{d_i^+ + d_i^-} \tag{6.7}$$

Table 6.7 Comparative estimate and ranks of the attributes

Attribute	$\boldsymbol{CE}^*$	Ranks
Status of behavior/habits	0.550	2
Status of road accidents	0.553	1
Status of safety and security	0.545	3
Status of transmissible diseases	0.479	6
Status of noise pollution	0.530	4
Status of air quality (dust particles)	0.490	5

6.3.2 Application of improved fuzzy weighted average (IFWA) approach based on left and right score

To evaluate the relative significance in terms of ranks of the attributes contributing to negative impacts of road construction, the second approach employed for the study is improved fuzzy weighted average (IFWA) method. The objective of employing this approach is to compare the ranks obtained from fuzzy TOPSIS approach. The procedure followed for the proposed approach is illustrated below:

Step-1: It deals with construction fuzzy decision matrix and fuzzy weight matrix. In this step, the data obtained in the form of linguistic terms for both ratings and weights of the attributes are transformed into fuzzy scale. The membership scale corresponding to linguistic ratings is constructed accordingly. Employing particular shape of membership function depends upon various factors, viz., range of data set (i.e., input and output), the grade of assessment along with the impact on the given attribute as well as on the opinion of the experts. In the present study, the triangular membership function has been employed due to its simplicity. It has also the ability to deal with ease when fairly limited relevant information about the linguistic expressions is available. As it overlaps and produces zero reconstruction error (Pedrycz, 1994). The fuzzy scale employed for both ratings and weights of the attributes is as given above in Table 6.2 respectively. This fuzzy scale has been decided upon opinions obtained from the expert working in the field of road safety audits and road safety management.

Step-2: This step follows the normalization of the fuzzy weight matrix of the criteria.

If $\widetilde{w}_{ij}$= (l_{ij}, m_{ij}, n_{ij}) (i = 1, 2, …, k) represents the weight rating given by the f^{th} expert., then in case of criteria which exhibits negative value the normalization of the weights is achieved by employing mathematical expression as shown in equation (6.8).

$$\left(\widetilde{w}_{ij}\right)_{Nr} = \left(\frac{n_{ij} - n_{ij}^{max}}{\Delta_{max}^{min}}, \frac{m_{ij} - n_{ij}^{max}}{\Delta_{max}^{min}}, \frac{l_{ij} - n_{ij}^{max}}{\Delta_{max}^{min}}\right) \tag{6.8}$$

where i = 1, 2, …, k; j ∈ c_{-}.

c_{-} corresponds to the set of criteria which exhibits negative value to the overall objective of the problem.

$n_j^{max} = max(n_{ij})$, $l_j^{min} = min(l_{ij})$, i = 1, 2, …, k.

$\Delta_{max}^{min} = l_j^{min} - n_i^{max}$.

Step-3: In this step, the left and right scores for both weights of the criteria and rating of the attribute are obtained. These are evaluated as shown using equations (6.9) and (6.10).

$$(L_{sc})_{Nr} = \left(\frac{\left(m_{ij}\right)_{Nr}}{1 + \left(m_{ij}\right)_{Nr} - \left(l_{ij}\right)_{Nr}}\right) \tag{6.9}$$

$$(R_{sc})_{Nr} = \left(\frac{\left(n_{ij}\right)_{Nr}}{1 + \left(n_{ij}\right)_{Nr} - \left(m_{ij}\right)_{Nr}}\right) \tag{6.10}$$

Step-4: This step involves the construction of left and right score matrices for both ratings of the attribute (as equation (6.11)) and weight of the criteria (as equation (6.12)) as shown below. Fig. 6.6 is the graphical visualization of the concept of the right and left scores. Table 6.8 and Table 6.9 shows the left and right scores achieved for both attribute and criteria.

$$((L_{sc})_{Nr}, (R_{sc})_{Nr})_A = \begin{pmatrix} [(L_{sc}),(R_{sc})]_{11} & \cdots & [(L_{sc}),(R_{sc})]_{1j} & \cdots & [(L_{sc}),(R_{sc})]_{1p} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ [(L_{sc}),(R_{sc})]_{i1} & \cdots & [(L_{sc}),(R_{sc})]_{ij} & \cdots & [(L_{sc}),(R_{sc})]_{ip} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ [(L_{sc}),(R_{sc})]_{k1} & \cdots & [(L_{sc}),(R_{sc})]_{k1} & \cdots & [(L_{sc}),(R_{sc})]_{kp} \end{pmatrix} \quad (6.11)$$

$$((L_{sc})_{Nr}, (R_{sc})_{Nr})_{CW} = ([(L_{sc}),(R_{sc})]_1 \quad \cdots \quad [(L_{sc}),(R_{sc})]_j \quad \cdots \quad [(L_{sc}),(R_{sc})]_p) \quad (6.12)$$

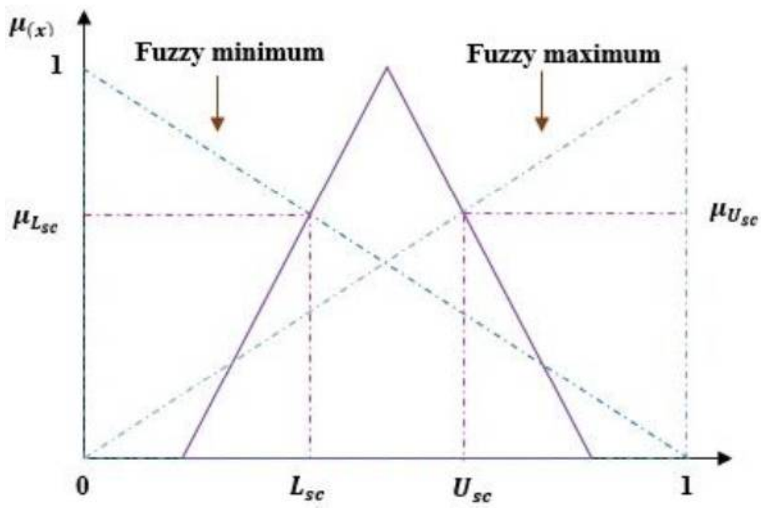

Fig. 6.6 The concept of $[(L_{sc}, R_{sc})]$

Table 6.8 Left and right interval ratings of the attribute

Attribute	Condition before road construction		Condition after road construction	
Status of behavior/habits	0.443	0.603	0.402	0.559
Status of road accidents	0.455	0.601	0.439	0.592

Status of safety and security	0.413	0.572	0.396	0.552
Status of noise pollution	0.234	0.369	0.253	0.388
Status of transmissible diseases	0.352	0.511	0.358	0.517
Status of air quality (dust particles)	0.252	0.392	0.308	0.449

Table 6.9 Left and right interval ratings for the weights of the criteria

Criteria	$(\boldsymbol{L_{sc}})_{\boldsymbol{Nr}}$	$(\boldsymbol{R_{sc}})_{\boldsymbol{Nr}}$
Condition before road construction	1.250	1.260
Condition after road construction	0.857	0.939

Step-4: In this step, the fuzzy weighted average for each of the attribute is calculated and is expressed as the interval of lower and upper bound value as $[(\theta_i)^{Lb}, (\theta_i)^{Ub}]$. Let for an attribute the left and right scores for both rating and weight be $r_{ij} = [(L_{sc}, R_{sc})_{ij}]$ and for the weight as $w_j = [(L_{sc}, R_{sc})_j]$, therefore the fuzzy weighted average for the attribute in terms of upper bound value is expressed as below in equation (6.13). Table 6.10 shows the lower and upper bound values for the attributes.

$$(\theta)_i = \left(\frac{w_1 \text{ x } r_{i1} + w_2 \text{ x } r_{i2} + \cdots + w_p \text{ x } r_{ip}}{w_1 + w_2 + \cdots + w_p}\right) \tag{6.13}$$

where i = 1, 2, …, k and, $(L_{sc})_j \leq w_j \leq (R_{sc})_j$, j = 1, 2, …, p, $(L_{sc})_{ij} \leq r_{ij} \leq (R_{sc})_{ij}$ j = 1, 2, …, p.

Table 6.10 Lower and upper bound values for the attribute

Attribute	$(\boldsymbol{\theta_i})^{\boldsymbol{Lb}}$	$(\boldsymbol{\theta_i})^{\boldsymbol{Ub}}$
Status of behavior/habits	0.426	0.573
Status of road accidents	0.448	0.595
Status of safety and security	0.406	0.558
Status of noise pollution	0.242	0.382
Status of transmissible diseases	0.355	0.515
Status of air quality (dust particles)	0.275	0.431

Step-5: In this step, the final score of the attribute is calculated as the average of the lower and upper bound value of the attribute (as given in Table 6.11), which is then employed to rank the attributes. It is calculated as shown in equation (6.14).

$$(\theta_i)_{AVG} = \left(\frac{(\theta_i)^{Lb} + (\theta_i)^{Ub}}{2}\right) \tag{6.14}$$

Table 6.11 Average IFWA value related to lower and upper bound interval

Attribute	$(\boldsymbol{\theta_i})_{\boldsymbol{AVG}}$	Ranks
Status of behavior/habits	0.500	2
Status of road accidents	0.521	1
Status of safety and security	0.482	3
Status of noise pollution	0.435	4
Status of transmissible diseases	0.312	6
Status of air quality (dust particles)	0.353	5

6.4 Results and discussion

The data has been collected through a questionnaire for the participants belonging to focus groups. Though, it has been presumed that there might be variation in the data collected for different participants belonging to focus groups, as they may have different viewpoints on negative outcomes of the constructed rural roads. But it has been observed that the perceptions of the different participants shows negligible variation in their viewpoints. Considering this, assessment has been performed by taking all the participants as one data set. Moreover, a sense of insecurity is observed after the deliverance of rural (PMGSY) roads in the perception of the participants during the focus group discussion. It is also revealed that most negative impact that has been materialized is the possibilities of minor accidents which are quiet often with high number of occurrences, whereas the possibilities of major accidents are low as compared to minor accidents.

The habitations connected by these road connectives have none of the facilities such as schools, markets, hospitals within the locality. Thus, making the inhabitants to travel long distances to reach them. Most of the inhabitants usually prefer two-wheelers or bicycles for traveling, apart from other local public transport facilities. In some cases, it is observed that the inhabitants travel by walking if the distance to reach the nearest facility is less, thereby increasing the vulnerability of the inhabitants. However, the study is only focused in assessing the exposure and vulnerability of the inhabitants along the selected road stretches. The data has been collected for attributes, viz., status of road accidents, status of transmissible diseases, status of ill habits/behaviour, status of safety and security, status of air quality, and status of noise pollution. The final scores and the ranks for each of the attribute assessed is shown below in Fig. 6.7. The attributes are ranked in terms of their relative significance. To assess their relative importance proposed methodology employs fuzzy TOPSIS and improved FWA techniques.

It has been observed that the status of road accident criteria has been observed to have high priority as primary attribute contributing to the negative impacts due to the construction of rural (PMGSY) roads. The reason could be poor and faulty designs of junctions as well as road geometry. Rural road connectivities have lower traffic volume but the risk of accident increases when these connectivities meet roads of high traffic intensity and volume. It has been perceived during data collection in case of selected road connectives that road junctions have poor designs (i.e., turning radii, improper flaring of road-sides, etc.) accompanied by poor illumination and lack of speed signboards. Besides this road junction, road alignment has also been found as a major concern which contributes to a road accident. The factors such as the width of the shoulder vary throughout the road connectivity for most of the selected road stretches. Furthermore, the transition from the curved section to a straight section of the road alignment is observed to be uneven. This has been observed more prominent especially in case of road stretch connecting *Charan ki Dhani* as well as *Jatan wali* habitations.

Moreover, it is also found that the number of acute horizontal curves along the road stretches are quite in number, thereby increasing the risk of road accidents significantly. Besides the status of road accidents attributes, the status of behaviours/habits and safety and security attributes are observed to be major attributes contributing in the form of negative impacts. This is due to the fact that improvement in connectivity to nearest towns or markets probably will make the rural youth to be involved in ill activities thereby changing the social environment of the habitations. Moreover, some of these roads pass crossectionally through the habitations to connect nearest economic centres. Thus, increasing the vulnerability of inhabitants in terms of safety and security to a significant extent. This has been observed in the case of 40% of selected road stretches. It is substantiated by the feedback of the inhabitants taken during focus group discussion that there has been about 30% increase in the theft and burgling activities which have increased safety concerns.

Apart from this, it can also be observed from Fig. 6.7 that the status of transmissible diseases attribute has been deduced as insignificant attribute. The cause might be due to the awareness within the rural community, as well as, maybe the inhabitants are not keen and comfortable in sharing this information as this might cause issues related to the status/pride of the individual or household. Therefore, ranking of attributes based upon their relative importance, helps to take necessary corrective action and to reduce the possible negative impacts instigated by the road construction.

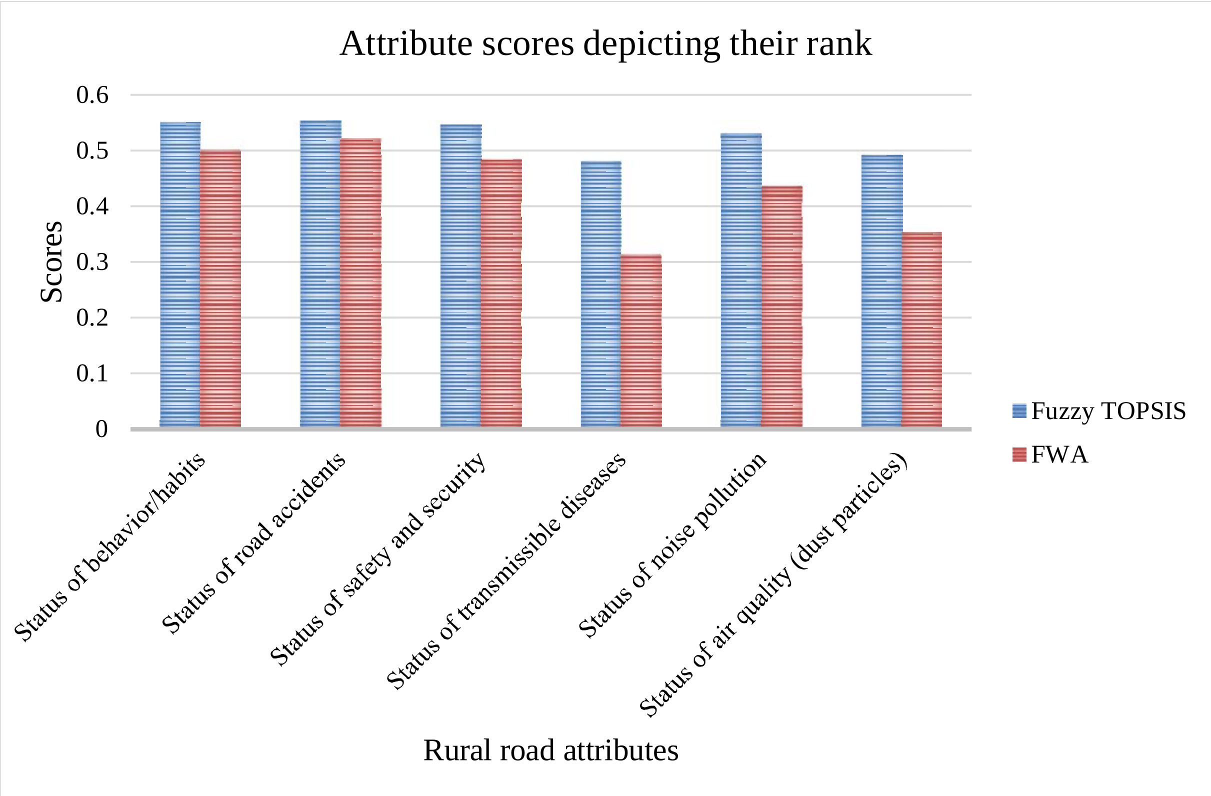

Fig. 6.7 Attribute scores depicting their ranks for fuzzy TOPSIS and improved FWA

6.5 Summary

Assessment of negative impacts due to the construction of rural roads is of prime importance in context with rural habitations. Moreover, the concerned authorities responsible for ensuring rural development lag to have a competent tool to identify the negative impacts of delivered infrastructure. Moreover, there are no instruments/techniques employed for assessing the negative impacts of rural road that can provide comprehensive conclusions. Considering these facts, the present chapter attempts to explore the application of fuzzy TOPSIS and improved FWA technique and develops a novel tool to assess the possible attributes that contribute to negative impacts on target population due to implementation of road infrastructure. The attitudes/perceptions of rural road users have been quantified to evaluate the impacts of each attribute that impacts rural development. They are assessed based upon their relative significance, the results obtained from both the methods are compared, and final attributes are identified by considering the intersection of both methods. The tool developed herein can be employed by the concerned authorities involved in rural policymaking and administration.

As the data about attributes contributing to negative impacts are imprecise and uncertain, the proposed model can consider the vagueness of such data with ease. Moreover, depending upon the requirement of the assessment, the tool can be conditioned and formulated. This will help the concerned decision makers to frame the tool in accordance with the data set. The proposed tool can be employed at a global level rather than just region specific. Furthermore, it will assist the concerned local authorities to devise corrective action plans depending upon the necessity, so that proper allocation of funds can be done effectively. However, from future scope viewpoint of the study, the cost-benefit analysis can be performed in amalgamation with the applied tool. Moreover, necessary educative actions can be implemented through policies, programs, and workshops thereby reducing the number of road accidents. Furthermore, from assessment viewpoint along with road factor, environmental factor needs to be assessed in depth in integration ArcGIS tool to have more comprehension.