CHAPTER 7
CONCLUSIONS

7.1 Conclusions

The thesis work presents a fuzzy based multi-criteria decision-making methodology for addressing the impacts of construction of rural (PMGSY) roads on rural households, for selected habitations located in Jhunjhunu district of Rajasthan state. The need and significance of performing impact assessment due to construction of rural roads have been discussed in Chapter 1. Along with this, an attempt is made to describe the shortcomings of the previous studies and initiatives taken by the researchers in developing impact assessment methodology. The major shortcomings of earlier studies towards assessing the rural road impacts were: (1) absence of integrated qualitative-quantitative decision support model for assessing the impacts of road infrastructure on target population; (2) lack of adequate and sufficient efforts made to address the issues with assessment of impacts in context of India; (3) lack of proper system to deal with the uncertainty involved in computing the attributes, which defined the impacts of rural road development, and to inculcate the participation and viewpoints of target population and (4) lack of appropriate methodology or a model which accounts socioeconomic impacts of transport infrastructure projects in India, and is capable of assessing the scope of impacts. Moreover, little research has been done to in understanding the social development goals while evaluating transport projects.

The significance of the present study has been emphasized by keeping in view of above-mentioned aspects. Chapter 1 discusses the aims and objects along with the scope and composition of the present study. Chapter 2 of the thesis, the literature review, demonstrates methods and advance methodology along with previous studies focused on assessing and identifying impacts instigated due to the construction of rural roads. It also illustrates the shortcomings of previous studies. It investigates contemporary literature considering: (i) quantitative and qualitative assessment techniques, and development of mixed-method approach, (ii) application of multicriteria decision techniques and their advancements in terms of integrated fuzzy based MCDM techniques, which can address the shortcomings associated with impact assessment models, (iii) use of computational intelligence approach for enhancing the assessment process, (iv) application of geographical

information systems (GIS) to enhance the interpretation of the outcomes of the assessment process from viewpoint of sustainable rural development.

The literature reflects that over the past two decades, there has been significant development in emphasizing incorporation impact evaluation methodologies while assessing the suitability of implementation of the road infrastructure program. Not enough efforts have been dealt in developing impact assessment models, which employs various integrated quantitative and qualitative techniques, fuzzy MCDM and computational intelligence approaches. Thus, there is enough scope to develop a novel and innovative impact assessment methodology by using fuzzy MCDM techniques such as, fuzzy TOPSIS, fuzzy Delphi technique, improved fuzzy weighted average method, and can be further strengthened by their integration with mixed-method approach and computational intelligence techniques. To achieve comprehensive and effectual assessment. Also, the existing literature distinctly indicates that there is an immediate need to develop an inclusive model framework in context with rural areas, especially for developing country like India.

In the present thesis not only, an attempt has been made to develop novel model, but also efforts have been made to incorporate several significant aspects which need adequate consideration to be incorporated while performing impact assessment studies. Considering this viewpoint, the ANFIS and fuzzy Delphi models assists as an excellent framework. They can address the issues such as cost and time effectiveness, uncertainty and ambiguity, incorporation of quantitative and qualitative data. The model employs data based upon the perceptions of the rural households (focus group participants), which provides a strong basis for assessment and to devise strategies for sustainable rural development. Models described in Chapters 3, 4, 5, and 6 of the thesis addresses the chronological flow of impact assessment. Each Chapter deals with the key issues by developing an appropriate models and provide suitable instruments and procedures.

Moreover, 'summary' section at the end of each chapter discusses the outcome in the form contribution of each model respectively. Significant findings along with contributions of this thesis are as listed:

- Prioritizing impact indicators considering sustainability: Chapter 3 of the thesis exclusively focuses on the significance and role of impact indicators. As, impact indicators/criteria are

important from the viewpoint of the assessment of rural road development. They are assessed using a mixed-method approach which integrates PCA and fuzzy TOPSIS techniques. The variance scores and ranking for each criterion/sub-criterion indicates its criticality due to the construction of rural roads. Developing a mixed-method approach helps to incorporate qualitative and quantitative aspects. It also assists researchers to identify appropriate impact criteria by overcoming the ambiguity of quantitative and judgments of qualitative aspects. Appropriateness of criteria is crucial from viewpoint assessing the impacts; for example, economic impacts can be defined by various criteria/sub-criteria, such as income from non-farm activities, income from agro-based small scale industries. Thus, findings like this act as guiding modules to the concerned decision makers to devise such a stepwise methodology in achieving sustainable rural development.

- Scree plot, rotated component matrices, monoplot, relative importance (ranks): The outcomes of the PCA, i.e., scree plot, rotated component matrices, monoplot help in identifying the critical criteria that have been impacted due to the construction of rural roads. 'SPPS software' and 'Analyse it-2016' tools have been used for the analysis. The scree plot helps in identifying the criteria in terms of components; each component represents variance; in this study total, 10 components have been retained and is based on the variance caused by 33 sub-criteria. 'Monoplot' provides information in terms of components and their interrelationships. Herein, the interrelationships between criteria/sub-criteria are depicted in reference to PC_1 and PC_2. The rotated component is a key output of PCA. It helps in identifying the relationship between components and the criteria/sub-criteria by forming different clusters. Based on the analysis, it has been revealed that 33 sub-criteria accounted a total 88.85% of variance in the data. It shows that these are the criteria which have been significantly impacted after the construction of rural roads. Furthermore, to have more comprehension, the outcome of the PCA is being compared with that of the fuzzy TOPSIS approach, based on their relative significance. From the analysis it is revealed that there is a need for proper distribution of health and education facility available to rural inhabitants, which is important from the viewpoint of overall rural development.

- Impact evaluation using computational intelligence and in terms of change: The scope of rural road impacts is evaluated using computational intelligence approach (ANFIS), it is used to assess the impacts on five criteria, viz., transport facility, income status, education facility, health facility and quality of the neighbourhood by using 33 sub-criteria, identified in Chapter 3 of the thesis. The results of the ANFIS approach are compared with fuzzy Delphi method to have an inclusive view of the impacts. Findings of the proposed methodology reveal that the income status and quality of neighbourhood criteria show significant impacts, whereas health and education facility criteria show a lower impact. Further, to have more understanding about the impacts concerning each habitation, they have been exemplified spatially using ArcGIS tool. Moreover, the percentage change in the condition of the criteria has also been evaluated, considering before and after rural roads construction.

- Cause-effect relationship: In Chapter 4, five models have been developed for the five criteria using ANFIS technique. The analysis shows that the The R-value for income status criteria model has been found high in both training and testing with the values of 0.7368 and 0.8621 respectively. The RMSE values have been found as 0.1152 and 0.1715 respectively, which are relatively low. Thus, the model performs better, as the value of R ranges between -1 to 1 and RMSE ranges between 0 and 1, higher the R with lower RMSE value is a good fit. Moreover, the model for quality of neighbourhood criteria shows a similar pattern for R and RMSE values of 0.9205 and 0.2617 respectively for training, whereas in testing, these values are taken as 0.8389 and 0.1209 respectively. Further, from the assessment of FDM, it can be observed that values of best non-fuzzy performance score for quality of neighbourhood criteria evaluated is the range of 0.6 to 0.9, which illustrates that the scores fall in the range of high category to an ultimately high category on the fuzzy scale. Also, the best non-fuzzy performance scores of income status criteria ranges from 0.51 to 1.0, which resembles that the income status of rural habitants is impacted significantly. Thus, it can be concluded that with a positive change in income status criteria, there is a significant change in the quality of neighbourhood of rural habitants.

- The need of policies and strategies: Considering the impacts of rural road construction on the target population based on the assessment performed (Chapters 3 and 4), the present

study certainly proposes the concerned policy and decision makers to implement schemes and policies to improve the status of criteria, viz., health and education facility. Though, there is an increase in the number of school going children and improvement in the mobility to health care centres, still it lags in certain aspects. For example, Due to non-availability of proper health facility in the vicinity, the rural inhabitants are required to travel a longer distance to reach the nearest and best possible facility. Thus, creating an immediate need to intensify their focus on improving them.

- <u>Impact on income status in terms of livelihood diversification</u>: The economic impact of road infrastructure development on the target population at the habitation level, in terms of livelihood diversification is assessed using fuzzy entropy measure and econometric model. The findings of the model of the study reveals that the probable reason for this trend might be the result of improvement in the access to the nearest market centres and reflects that the scope of livelihood diversification through non-farm activities has been minimal. Further, from econometric analysis it is observed that livelihood diversification is in the process, which is ascertained from the positive influence of a number of working age member's ratio over household income. Thus, it can be concluded that with the improvement in accessibility to the nearest economic centres the rural inhabitants are able to avail new employment opportunities. Also, this influence on income earnings of the rural households may have been caused due to absorption of individuals belonging to working age group. The assessment performed in this chapter yield some important insights which will assist the concerned policy makers in the implementation of different schemes and policies. There is requirement of necessary steps to be taken by the concerned policy and decision makers by providing subsidies and aids. This will help rural inhabitants to establish small scale livelihood enterprises, as well as, it also help them to enhance their agricultural production. Moreover, with promotion of non-farm employments through small scale livelihood enterprises will provide help in absorbing available labor resources.

- <u>The significance of assessing negative impacts</u>: In the negative impact assessment model two fuzzy multicriteria techniques (fuzzy TOPSIS and improved fuzzy weighted average method) have been employed to explore the negative impacts instigated by road construction on the target population. The study identifies the most negatively impacted

attributes, viz., air quality, vegetation cover status, noise pollution, transmissible diseases status, ill habits/behaviour status, safety and security, and road accidents concerning both physical and social environment, out of which safety and security, and road accidents are found to be significant. Assessment of negative impacts is necessary to evaluate the vulnerability of rural inhabitants and also necessary to strengthen their capacities. The analysis presented in this chapter will provide the groundwork for the concerned decision makers to focus in assessing and mitigating the impacts (negative) along with positive impacts, it will also assist them in devising corrective action plans depending upon the necessity so that proper allocation of funds can be done effectively, which will help them in achieving their intended goal of sustainable rural development.

- Comparative analysis: Comparative analysis has been performed to assess the robustness of the models developed herein (Chapters 3, 4, 5, and 6). It is performed by employing two different techniques for assessing the problem statement of the impact assessment methodology. The comparative analysis provides a strong basis to outcomes obtained from one technique by comparing it with the outcomes of other technique. It helps in developing inclusive assessment framework by considering the advantages of two different techniques and helps to identify the ideal and worst scenarios. This can be observed from the analysis presented in chapter 4. The analysis shows that quality of neighbourhood and income status criteria perform well in case of both ANFIS and FDM models, but in overall, ANFIS outperforms over the FDM based model in performance analysis.

- Indicator and zone priority: Integration of ArcGIS tool in Chapters 4 and 5 has helped in enhancing the understanding about the impacts. It helps in delineating the criteria which have had a significant or insignificant impact due to road construction. It also helps in identifying and improving the status of criteria which show insignificantly impact after the construction of rural roads, and helps in adopting schemes, policies, and strategies for improving their current state. It also helps to identify the scope of impacts considering criteria concerning habitations and blocks.

- Versatile models: Chapters 3, 4, 5, and 6 develop inclusive models which integrate both quantitative and qualitative data (i.e., perception of the focus group) to assess the impacts

instigated by construction of rural roads in habitations selected in Jhunjhunu district of Rajasthan state of India. For example, the ANFIS model considers the advantage of both fuzzy logic and neural networks. It learns the input data and interprets the outcomes with minimal error. Moreover, it can accommodate any changes in the input data without any complexity. Similar observations are also noticed with F-TOPSIS and improved fuzzy weighted average methods.

- Sustainable rural development: The thesis emphasizes on achieving sustainable rural development through road infrastructure development in integration with supportive schemes, policies, and workshops. The idea of sustainable development can only be achieved when the concerned decision makers have a proper view of the impacts instigated by road construction. Improvement in physical mobility helps in achieving sustainability outcomes in context with rural areas. The livability conditions of rural individuals with improvement in rural roads as they provide enhanced access to necessary education and health services, markets and increase food security. Moreover, in consideration with sustainable development point of view rural roads capacitate rural inhabitants with proper information. This helps in reducing the vulnerability of rural inhabitants, which assists them to participate in social development programs. Such development also leads for sustainable livelihood, which helps the rural inhabitants to recover and handle the economic shocks and stresses. Considering both future and their current condition without undermining the natural resources, as well as, assets available.

- Policies, schemes, and action plans: Road infrastructure alone cannot help in the overall development of rural habitations. Though they facilitate mobility and accessibility to services (economic and social facilities), thereby helping in poverty alleviation of rural households. But to enable sustainable rural development, policies, schemes, and action plans also play a vital role. Therefore, Chapters 3, 5, and 6 of the thesis emphasize and recommends appropriate policies and action plans in accordance with the intended goal of concerned decision makers from the viewpoint of achieving sustainable rural development. The action plans, for example, subsidies, should be provided for the establishment of livelihood enterprises, as well as, financial aids are to be provided to enhance agricultural

productivity. Moreover, with promotion of non-farm employments through small scale livelihood enterprises will provide help in absorbing available labor resources.

- Capturing biasness of uncertain data: Advanced fuzzy-MCDM methods have been applied in chapters 3, 4, 5 and 6 respectively. One of the main goals has been to deal with the uncertainty related to randomness in the data gathered, as well as, to overcome the imprecision caused by the judgments of the focus group participants.

- Global relevance: The models proposed in this study provides a user-friendly decision support system. They can account the complexities and distinctions related to the impact assessment process with ease. The models can be employed with a global perspective and not just restrained to region-specific, considering from the viewpoint of applicability, and because of its ease, flexibility, time and cost-effectiveness, and its ability to incorporate the uncertainties and ambiguities associated with the data, as well as, assessment process.

The thesis attempts to develop novel models that channelize the quantitative and qualitative aspects of the data, academic investigation, the perception of stakeholders focus groups, and action plans into an efficient decision support system. From value addition viewpoint, the thesis is innovative and captures different aspects with consonance, by considering that rural roads impacts are of different in nature, scope, and duration, especially in the case of desert state of Rajasthan. Furthermore, it offers a more defined way to assess rural development and road infrastructure facilitating it. The outcomes of the assessment provide necessary insights to the concerned decision makers in understanding which of the aspects need high priority in achieving their goal of sustainable rural development. Though, models are well-equipped, stable and can perform the assessment, still there are some shortcomings associated with them. Table 7.1 illustrates some of the significant strengths and shortcomings of the models.

Table 7.1 Merits and demerits of various models used in the study

Models	Strengths	Shortcoming
PCA using 'SPSS' and 'Analyse it-2016' software	It reveals the relationship among variables and is simple from an assessment point of view. It helps in data reduction	It does not necessary information on the cause-effect relationships of indicators provide governing equations which can explain
Fuzzy TOPSIS	It is less complex to perform and compares the relative significance of the criteria considering the ideal and nadir values	It neglects the criteria/sub-criteria if the relative significance is equal to "0"
ANFIS	It provides results with robustness, provides room for the use of crisp inputs and outputs. It has the ability to interpret the data comprehensively	It does not deal with large input data which known as "curse of dimensionality", but this shortcoming can be handled by using subtractive clustering techniques
Fuzzy Delphi	Represents uncertainty in a precise manner by adjusting the membership functions accordingly	Time-consuming
Improved fuzzy weighted average method	Less complex easy to perform	Involves a huge number of arithmetic operations

7.2 Future Scope

It can be distinguished as a unique and innovative attempt towards the assessment of impacts instigated by the rural road infrastructure on the target population, based upon its contributions. However, there is enough scope of addition to the attempt presented in this thesis from a futuristic study point of view. The futuristic study depends completely upon the extent and data availability,

especially in case developing countries like India, were it is significant due to data insufficiency. As, the data gathered for the study is limited to the only district of Rajasthan state of India, and hence limits the extent of the study. It is one of the limitations of the present thesis. Moreover, only immediate impacts have been captured, and there is a need to focus on long-term impacts, as well as, there is a need to understand the cumulative impacts of such infrastructure development. For a more comprehensive picture of the impacts of these rural (PMGSY) roads, there is a need to have a relative study, i.e., the boundaries of the study area are to be extended.

It can further be improved by capturing the data based upon the distinction of climatic regions of the state, as well as, by extending it to others states to have a comparative assessment, thereby helping the concerned decision makers to device effective policies and action plans accordingly. This kind of comprehensive and complete methodology can be helpful and will have a vital role in making public policy at country level. Also, different models, i.e., along with community level, a household level-based study has to be developed; such incorporation will enhance the model outcome and understanding of such infrastructure development. Moreover, there is a need to extend the scope of the study from the viewpoint of assessment of equity among the rural population with special reference to women and other especially marginalized groups.

Overall, it may be highlighted that there is an urgent need for applied research work for conducting an impact assessment and also to analyze the interrelationship of such infrastructure development with other public programs and services initiated by the government from the viewpoint of rural development. As impact assessment not only helps in providing better quality assistance satisfying to the needs of the rural population but also reinforces the belief of democracy, by permitting significant involvement of target population, who are likely to be impacted the most, by such infrastructure development.