CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

In the past few decade's importance in the construction of rural roads has increased substantially at the global level. Connecting villages with proper road network are important from the development point of the nation. Rural roads incur benefits such as decreased travel cost and reduced travel time to reach the nearest facility such as health, education, and markets, while they increase access to employment opportunities for the target population (Tsunokawa and Hoban, 1997). As a result, initiatives are being taken by various regional and global investment agencies such as Asian Development Bank (ADB), International Development Association (IDA), World Bank, etc., in the development of rural roads. Rural roads often yield positive impacts in terms of socio-economic benefits but can also bring substantial negative impacts on the target population as well as on the surrounding environment; these impacts may either be long term or short term. As a result, the significance of assessing these impacts has become more evident and has created a need for new methodologies and techniques to be incorporated into the planning and management of rural roads.

However, many government agencies and concerned decision makers get hesitant to perform impact evaluations due to complexity of the problem, temporal variations and socio-political dynamics. Though, if performed they are either criticized as unable to answer the outcomes or not being carried out with required analytical rigor. Apart from this, there is often a constraint that the data being destitute and limited. However, if an impact assessment has been performed with proper planning at an early stage of the project, it will help to concerned policy and decision makers, to identify the appropriateness of the program effectively. Assessment of rural road impacts particularly in the case of developing countries helps to concerned policymakers to identify the difference made by the construction roads in the socio-economic condition of the target population. Impact evaluation can provide rightful information whether the delivered program has reached intended recipients or has been wasteful so that it can be redesigned or improved. The knowledge perceived from the impact assessment study will act as a significant input in the designing of such infrastructure projects and programs of the future.

Collectively, impact evaluation substantiates the effects of the delivered infrastructure in the form information by determining its relative cost-effectiveness compared to other programs and yields insights into whether the program has been able to deliver or not, as intended. It also provides evidence on different programs and schemes which are likely to help concerned authorities to achieve their goals. Despite the assessment of rural roads impacts being an important topic, there is some dissatisfaction with the evidence that demonstrates the impact of rural road investment. Moreover, very little information is known regarding the magnitude of the rural road impacts as well as their non-pecuniary benefits, whereas plenty is realized regarding their investments (cost). Besides this there have been quite a several impact assessment studies, giving varying results, much of them have been anecdotal. Van De Walle (2009) concluded that there had been relatively few studies with proper controls, performed by employing rigorous analysis and statistical testing.

Though, rural road investment has been substantiated by several impact assessment studies (Ahmed and Hossain, 1990; Van de Walle, 2002; Lokshin and Yemtsov, 2005), it has been perceived that a few of the studies tend to treat this area of focus as a black box, without considering their scope (most or least), and without identifying in what circumstances the impacts are actulized, reasons being inconsistency associated with the data. Also, the methodological framework of these studies inhibit them from linking road construction and different impact indicators. Apart from this, impact assessment studies received less importance and had little motivation in the planning of rural road investment. Moreover, rural road development projects have been chosen based on available budget, cost-analysis of transport user, and are prioritized crudely on thumb rules. In general, most of the studies focused on impacts in terms of accessibility to the food market and public services, without any consideration to other factors which may increase or reduce the status of positive impacts. Although enhanced accessibility is a positive impact, greater accessibility to market and social services does not always entail positive impacts on the target population.

As a result, appropriate assessment methodology is required for analysis and identification of impacts comprehensively, which will be assistance in the development of an effective decision support system for managing overall rural development, as well as, to minimize negative impacts by systematic incorporation and formulation of appropriate strategies. However, rural road impacts are broad and complicated, and their assessments not only involve technical understanding but

also require incorporation of social, economic and environmental aspects. Also, they are to be holistically and realistically investigated so that to minimize the inherent uncertainties and complexities associated with data effectively, thereby overcoming the risks of incompetent assessment. Thus, assessment of a rural road impact is a multifaceted concept, which can be analyzed using extensive techniques under a fuzzy multi-criteria decision-making framework and computational intelligence. Therefore, this study primarily aims to develop a suitable methodology for assessing rural road impacts for some selected road (PMGSY) stretches by using fuzzy based multi-criteria decision-making approaches and computational intelligence techniques.

This literature review chapter provides a general overview of studies and techniques employed to assess the impacts due to the construction of rural roads on the target population. The chapter is divided into three sections. The first section of the chapter concisely outlines some of the studies dealing with the assessment of outcomes of rural road construction. The second section briefly reviews existing studies which have been developed at the international and national level (specifically exploring studies which attempted to assess the impacts of PMGSY roads). This section also outlines various methodological approaches along with their advantages and disadvantages. The final section of the chapter concludes by identifying and highlighting the research gaps.

2.2 International and national studies on assessing the impacts of rural road construction

2.2.1 International studies

Impacts induced by rural road construction consists of direct and indirect effects. Direct impacts are quantified in terms reduction in travel time (i.e., travel time to reach work, hospitals, schools, markets) as well as savings in terms travel cost and fuel, whereas indirect impacts are in terms of increased income and other well-being dimensions. Therefore, impact assessment methodology agglomerates evaluation and distribution of direct and indirect impacts along with identification of their scope. Conventionally, during 1990s rural road impacts have been assessed under econometric framework using cost-benefit analysis and internal rate of returns (Ahmed and Hossain, 1990). They have been assessed using consumer surplus and producer surplus approaches

under cost-benefit analysis framework using macro-level data, and of these two mentioned methods "consumer surplus" approach is best-suited in assessing the impacts of rural road construction (Robinson, 1999). However, to overcome the shortcomings of traditional cost-benefit analysis, Van de Walle (2002) proposes a diversified hybrid operational approach to assess the benefits/impacts of rural road construction through community participation.

The literature on the impacts of rural roads in terms of cost-benefit analysis is abundant. Majority of the works do not overcome the problem of endogeneity associated with the assessment process (Deininger and Okidi, 2003). However, more reliable and robust evaluation studies of rural road impacts which can handle efficiently the endogenous nature of the problem have been reported in the literature (Lokshin and Yemtsov, 2005; Mu and Van de Walle, 2007). These studies employed techniques of experimental (randomization technique) and quasi-experimental approach, viz., double-difference method, propensity score approach, matching method, and instrumental variable technique, separately or in combination for evaluating the impacts. But, among all the techniques of a quantitative approach (i.e., experimental or quasi-experimental designs), randomization technique is considered as the most rigorous techniques and produce the more precise (i.e., unbiased) results. The aim is to determine the scope of the impacts to be more specific (Van de Walle, 2009; Khandker et al., 2009).

The double-difference method and propensity score approach require panel and household data for the assessment, which is difficult to obtain, whereas if household data is used it lacks the temporal dimensions. Therefore, to have a robust evaluation, such cross-sectional data can be well assessed by using the variable instrumental technique (Gachassin et al., 2010). But, in practice, it is often difficult to find convincing instrumental variables. However, quantitative approaches suffer from the criticisms that they are time-consuming and they are expensive from the point of view of data generation (Stern et al., 2012). Therefore, to overcome these critiques qualitative approach has played a significant role in impact evaluation. The aim has been to provide realistic, appropriate and cost-effective affirmation of the impacts of road construction based upon the perception of the rural inhabitants (Hammersley, 2013). Copestake and Remnant (2015) showed the credibility of qualitative approach in assessing the impacts of infrastructure intervention by developing qualitative impact protocol (QUIP) model.

However, considering the acclaims and criticisms of both quantitative and qualitative approaches, the literature suggests that quantitative approaches are to be complemented by qualitative approaches for better illumination of the impacts (Palinkas et al., 2015). The mixed-method approach is one such technique which provides better insights on the impacts/benefits of the development program as compared to either quantitative or qualitative assessments alone (Smajgl and Ward, 2015). Ortiz et al. (2018) proposed a mixed methodology for prioritizing the social and environmental impacts. The study is based on assessing and prioritizing the impacts using multicriteria decision-making technique (MCDM). The study put forth's that prioritizing the impacts using MCDM technique can encompass different assessment criteria and provides enhanced understandings about the social vulnerability of rural households.

2.2.2 National scenario

A few studies have demonstrated improvement in rural life with the launch of Pradhan Mantri Gram Sadak Yojana (PMGSY) in India, a flagship program. PMGSY roads have helped to transform the rural economy significantly and have been widely acknowledged by different studies. Some attempts have been made to assess socio-economic impacts of PMGSY roads in the states of Assam, Himachal Pradesh, Madhya Pradesh, Mizoram, Orissa, Rajasthan, Tamil Nadu, Uttar Pradesh, and West Bengal. Most of the literature in context with an assessment of rural roads in India are based on regression analysis, cost-benefit approach, before and after studies, double-difference approach, etc. A study by Majumdar (2002) stated that rural road infrastructure has positive effects on agriculture output. The author quantified impacts using regression analysis, highlighting that road infrastructure significantly impacts agricultural productivity.

A study by Altaf (2010) in Madhya Pradesh India, mainly assessed the impacts on income due to PMGSY roads. It demonstrated how travel time is reduced while traveling from a given habitation to different locations such as district headquarters, block headquarters, hospitals, banks, marketplaces and bus stops using all other weather roads. The research is based on before, and after studies of assessment, it mainly focuses on assessing the percentage change in the economic condition of rural inhabitants. Mukherjee (2012) demonstrated the effects of PMGSY road construction on school enrolment using regression analysis. Another study by Lokesha and Mahesha (2016), employed descriptive research to assess the impacts of rural (PMGSY) roads on

agricultural development. The findings of the study state that with improved road infrastructure there is an increase in agricultural productivity. Asher and Novosad (2018) used regression discontinuity design to assess the impacts of PMGSY road construction on the economic development of rural households. The study emphasizes that no major changes occurred in the income and asset outcomes of the rural inhabitants.

Adukia et al. (2017) used an instrumental variable technique. The author focused on assessing the education investments as the outcome of economic development due to the construction of rural roads. Most of the impact assessment studies specifically in context with PMGSY roads have focused on assessing the economic benefits of road construction. These studies lack to estimate the social vulnerability of the target population. Thus, considering the literature on assessment of overall impacts of PMGSY roads, there is a need to develop a comprehensive novel methodology which can capture the change in both social and economic phenomenon of rural inhabitants effectively.

2.3 Methodological approaches used to assess the impacts of rural road construction

2.3.1 Quantitative methods

2.3.1.1 Experimental designs/techniques

Experimental designs of impact assessment are also known as randomization techniques; these are generally considered as best and robust evaluation techniques. This approach aims to identify the impacts of the delivered scheme/program, and specifically, to assess the extent of these impacts. The main viewpoint of this technique is to assess the effectiveness of the scheme by comparing the supposed impacts of the target population with that of the control population. This is achieved by selecting the target population and control population randomly. In experimental design, the target population should have statistical equivalent characteristics as that of control population, and the intervention that they are receiving should be identified as that of the control population. Furthermore, both of the groups (target and control populations) are selected such that they do not differ in their socio-economic background. Thus, random selection assures the elimination of

biases caused in the selection process of both target population as well as the control population, which typically influences the overall impact assessment process.

Although the biases in selecting the groups are being eliminated effectively, still randomization technique suffers from some of the anomalies. The technique is not feasible from the viewpoint of the overall impact assessment process, as there are possibilities that an error may be induced in the assessment process due to a random selection of the groups (Barnow and King, 2000), as well as with poor sample size. Bigger the sample size lesser is the error induced. Furthermore, to have better elucidation about the impacts instigated, selection of the control group has to be done in such a way that no supplementary program has been delivered nor has been accessed by the control population. There are also possibilities that the selection of groups may create political and ethical issues. Therefore, it is necessary to sustain requirements, a random selection of target and control populations are to be done carefully. As that it may substitute in the assessment process and affect the outcomes of the assessment (Suresh, 2011). Moreover, experimental designs are time-consuming and are expensive, particularly the process of data collection.

However, in case of interventions such as roads, the difficulties arise in the random assignment. Roads are laid geographically according to need and are associated with several factors which influence the outcomes. Furthermore, on the contrary, it is possible that they might be laid due to the economic potentiality of the area or due to political influence. Also, a problem of endogeneity may come into view as the impact instigated by them reflect at the community level as some of the individual factors remain unobserved. In view of these factors, the potential of employing experimental designs in assessing impacts instigated due to road interventions seems low. Moreover, most of the impacts instigated by road intervention are indirect and preferably take time to surface, so that they can be accounted.

2.3.1.2 Quasi-Experimental designs/techniques

Quasi-Experimental techniques are reliable when randomization techniques are found to be difficult and ineffective in evaluating the impacts instigated by the intervention on the target population. Although, these techniques are based upon the same basic concept as that of randomization techniques, except they do not involve random assignment of control groups (Frondel and Schmidt, 2005; Ferraro and Pattanayak, 2006). These can be broadly be classified on

the basis time, i.e., Ex-Ante (before the infrastructure intervention) and Ex-Post (after the infrastructure intervention) designs, but more preferred are Ex-Post Quasi-Experimental designs. These techniques are cost-effective and are often less time-consuming. These are further divided based upon the observable and unobservable characteristics into two groups. Techniques like matched comparison and multivariate regression methods deal with observable traits. On the other hand, techniques, viz., double difference, instrumental variables methods, and reflexive comparison consider unobservable traits (Ferraro, 2009). Matched comparison technique is the most widely used Quasi-experimental approach.

Matched comparison technique: In the matched comparison method, participants who belong to the control group are selected from the pool of individuals/households which resemble in characteristics like that of the target/ treatment population. Matching methods are generally used to identify causal impacts, as well as they can also be used to assess premediated effects like disparities among gender and ethnic groups (Schneider et al., 2004). Matching methods requires huge data (household/individual) set and indicators which are influenced by the intervention. But it is difficult to identify appropriate indicators that can be used to match the control group to the treatment group. However, this shortcoming is surmounted by using propensity score matching technique. Herein, scores of each indicator which define possible impacts of the intervention on the treatment and control group are scaled on a single probability score (Weitzen et al., 2004). Thus, the impacts are evaluated by taking the difference in mean scores of the control and treatment groups. Unfortunately, if any imbalance occurs in the use of indicators between the treatment and control group, then disparity will also be induced in the propensity scores of the groups as well.

There is considerable debate on employing matching methods for impact assessment, as some of the researchers consider it as unsuitable considering its correctness and usefulness. While other researchers note it as quite effective if the condition and assumptions of the technique are endured properly (Orr, 1999; Dehejia and Wahba, 2002). Among the operational merits of this method, the main advantage is that it is cost effective and consumes less amount of time in the overall assessment process if compared to experimental approaches. Further, it can be performed by employing the data set available and does not require exhaustive planning. However, the principal disadvantage of this method is that it does not consider unpremeditated issues associated with the selection of indicators and control group.

Multivariate regression: Assessing of impacts using multivariate regression analysis is done by focusing on one indicator of interest and by holding the effects of other variables constant or invariable. Here, the impacts which are of interest to the concerned policy makers are assessed by regressing single indicator concerning various measured aspects (individual and environmental) that may have a significant effect on the outcome of the delivered intervention. The variable of interest is selected in such a way that it has marginal impacts on the outcome of the intervention deployed, thereby capturing the effects of other indicators. The technique helps in the unbiased assessment of the impacts only when all the indicators along with variable of interest considered for the study are significantly associated with the possible impact outcome. Yet, it will be incompetent if the developed analytical model framework fails to consider various aspects such as biases associated with the selection of participants (comparison group). Generally, the regression technique is used in combination with techniques like matched comparison methods, random assignment designs, double-difference approach, etc.

Reflexive comparison: This technique of Quasi-experimental design does not account the selection of the control group for the assessment. It considers the treatment group as a control group and estimates the outcome impacts of the intervention by assessing the change in the condition of the impact indicators before to after implementation of the program. Thus, the biases associated with the selection of control group due to unobservable characteristics are eliminated. It requires panel data for the assessment of the impacts. Although, the technique is not as competent when compared to experimental designs and matched comparison methods, it is still employed because of its time and cost-effectiveness in many developing countries for impact evaluation. A possible disadvantage associated with this technique is that it cannot disentangle the effects which may have occurred without the influence of the program being implemented. Therefore, it creates a need to employ indicators which only considers the effects of the intervention. Otherwise, it will lead to biased estimates; however, such data is difficult to capture.

This method is useful when it is difficult to establish control group and is widely used in assessing the impacts of interventions where it is possible to capture the treatment population fully (i.e., complete participation of the treatment population). Assessments, for example, impacts of educational policies on school enrollment and rate of graduation are being performed by employing a reflexive comparison approach.

Double-difference/difference-in-difference: In this method, the impact estimation is performed by assessing the difference (the first difference) between the condition of impact indicators before and after implementation of the program (e.g., roads) for the treatment group, and then by taking the difference (the second difference) between condition of the variables before and after the deliverance of program (e.g., roads) for the control group. Here, the notion is that, if there exists no difference in the program (e.g., roads) indicator between treatment and comparison group, and the difference does not change over a given period time, then such indicator is to be eliminated from the process of impact assessment. Operationally, double difference method is performed in conjunction with regression analysis, where regression is performed between the variable of interest (for which impact has been measured) as the dependent variable and set of indicators which contribute to the change as independent variables.

The method is based upon the assumption that some of the indirect impacts are time invariant. This implies that there should be no time-varying measurable difference between treatment and control groups before the implementation of program/intervention, in terms of the characteristics of indicators which define impacts. But such assumptions are inappropriate based upon considerable evidence, for example, if there has been a decline in the labor market as well as in the earnings and expenditure of the target group before implementation roads. However, at the same it may be possible that such condition may not prevail in case of the control group, thus contradicting the assumption that no time-varying difference exists between control and treatment group (Heckman et al., 1991).

Instrumental variables: This is another approach which controls biases induced in the assessment process due to unobservable effects. In case when the evaluators regress the indicator, which is supposed to be impacted due to the implementation of the intervention, concerning other independent variables for both target and control groups. There is a possibility that error may be due to unobservable characteristics which may yield into bias estimates of the impact. In such a case, econometric corrections (also known as "instruments variables") are substituted to counter/correct the unobservable effects. Therefore, the evaluators are needed to choose an appropriate variable for correction, which can be highly correlated with the program implementation but does not affect its outcome (Heckman et al., 1991). The contemporary literature identifies two types of instrumental variables corrections. First, a correction can apply

by using those instrumental variables which are related to the implementation of the intervention but does not affect the outcome of the assessment process. However, in practice, it is difficult to identify such an instrumental variable. The second correction is known as "Heckman two-stage estimator." In this case, the initial stage follows finding of probabilities of those instrumental variables which can significantly be correlated with the implementation of the program, and in the final stage the unobserved characteristics are adjusted statistically using the results of the first stage (i.e., variable with the highest probability), so that impact assessment performed remains unbiased (Blomquist, 2003). However, this approach has rarely used in the impact assessment studies due to problems associated with the selection of variables.

Although, different methods (experimental and quasi-experimental) discussed above are advantageous in assessing socio-economic impacts effectively, but there are certain limitations associated with them as listed below in Table 2.1.

Table 2.1 Classification of impact assessment methods used for socio-economic impact assessment

Methods (s)	Advantages	Limitations
Randomization	Suitable in the case where the scope of intervention is limited	It may lead to bias assessment due to the presence of sampling error
Multivariate regression	Suitable in the case when there is a need to identify the interaction between the attribute of interest	It may lead to erroneous and misleading results; it cannot be used to assess qualitative data; it is complicated
Matching methods or constructed controls	Suitable in the case when randomization methods are not suitable for assessment; it offers a few benefits in comparison with traditional methods; it does not depend on baseline data	It only considers observed variables; it can also produce bias estimates due to the

		presence of latent variables
Reflexive comparisons	Suitable in the case when baseline survey and follow up survey are involved; it can address the biases associated with unobserved variables; it is also suitable for assessing the effects of broad policy or intervention, which involves complete participation of stakeholders	It can produce biased estimates in the case where several variables defining the intervention are inadequate
The double difference or difference-in-differences	Suitable in case of perceptive interpretation; it can handle either individual or group level data efficiently; it also deals with the variables which are aggravating and unobserved, given that they are not time dependent	It requires baseline data for assessment, less reliable; assessment may be associated with biases
Instrumental variables or statistical control	Suitable in case of assessing causal effects for substantive interventions; it allows consistent assessment of explanatory variables associated with measurement errors	It is difficult to find substantial instrumental variables for a comprehensive assessment

2.3.2 Qualitative methods

Along with quantitative techniques, assessment of impacts is also performed by using qualitative techniques so that underlying impacts are estimated in a comprehensive way (Valadez and Bamberger, 1994). Qualitative methods emphasize on understanding the impacts and are perceived by taking perception of the target population (Mohr, 1999). As the perception of the target population provides necessary insights into the ways in which the program is perceived, it helps to enumerate the possible impacts of the program. However, conventionally quantitative techniques have been used to be the core for assessing the impacts of program implementation, whereas qualitative techniques have been used in integration with other evaluation techniques.

The qualitative approach uses open-ended methods for the entire assessment process, i.e., right from designing, data collection till the analysis phase. The methodologies used in qualitative impact assessments are the techniques developed for rapid assessment of the condition and rely on the knowledge of the participants' or through a participatory approach. In qualitative assessment participants/stakeholders are involved in every stage of the assessment process. The advantage of these techniques is that they are flexible and can be tailored according to the requirement of the evaluation process, thereby enhancing the findings by providing a better understanding of the priorities of the stakeholders. Qualitative assessment can be implemented by using a range of data collection tools, such as oral records, focus group discussions, mapping practices, public interviews, and transects which have been used for data collection, and they need pretesting similar to that of structured survey methods.

Despite its flexibility, this approach suffers from the drawbacks such as the subjective nature of the data set, unavailability of the comparison group, robustness associated with the assessment process, etc. The reliability of qualitative data depends upon the expertise (i.e., training, methodological skills) of the evaluator. The enumerators are required to be sensitive towards the social and cultural aspects of the treatment group. Finally, assessment is difficult without a comparison group as it will not be counterfactual.

2.3.3 Fuzzy based multicriteria evaluation techniques

Impacts of rural road construction may be classified into various types and are defined accordingly. As discussed earlier, the assessment of impacts is the problem of a complex nature. It is dependent on various attributes and requires both qualitative and quantitative data. Also, it includes target population/stakeholders and their perceptions, and yield an extensive list of impacts to be addressed and balanced, to reach an assessment of merit. Thus, making it fundamentally a problem of diverse nature, though a number of techniques are available, still, they lack to address it comprehensively. Therefore, this calls for a methodology which can integrate the necessary data about the impacts, and at the same time, it considers the preferences of the stakeholders, to assess the overall implication of the intervention (roads). Multi-criteria decision making (MCDM) technique offer an appropriate basis to perform an impact assessment (Bonte et al., 1998; Caggiati

and Ragazzoni, 2000; Janssen, 2001). The technique is well known for its flexibility and robustness and offer a lot of other advantages.

It involves interaction between judgments of stakeholders, data gathered, and assessment processes (Stewart, 2005; Phoghat and Singh, 2013). Almost all the MCDM techniques have similar assessment procedure, i.e., development of a decision matrix of criteria using performance scores which integrates risk levels and uncertainties, but each of the techniques/tools synthesizes the data differently (Figueira et al., 2005). The research work of Ana Maria Esteves (2008a, 2008b), and Esteves and Vanclay (2009) have been the main reference which provides an appropriate basis on using MCDM which facilitates the integration of qualitative and quantitative approaches. In brief, there are several rationales for employing MCDM techniques: (1) to substantiate priority decisions of multi-stakeholder; (2) to generate a well-defined score of project impacts; and (3) to ensure appropriate transparency in the decision-making process by simultaneously facilitating learning and dialogue among stakeholders through appropriate participatory approach with relative merits.

MCDM techniques are time and cost effective; they can consider 'N' number of criteria with ease and are efficient from the point of view management and decision making (Zarghami and Szidarovszky, 2009). There are a number of MCDM techniques/tools available for impact assessment, viz., Multi-attribute Value Theory (MAVT), Analytic Hierarchy Process (AHP), Technique Order Preference by Similarity to Ideal Solution (TOPSIS), outranking methods such as Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE), Elimination Et Choix Traduisant la Realite (ELECTRE III) (Kiker et al., 2005). However, there is no any premediated condition, which specifies which tool is best suited for the impact assessment process. Therefore, necessary care is to be taken while selecting MCDM tool based on the risks associated with the error in the data gathered, outcome possibilities, and conflicting interests of various stakeholders (Pan et al., 2017; Singh et al., 2019; Vyas et al., 2019).

Analytical Hierarchy Process (AHP) first developed by Saaty (1980, 2000), occupies a significant position among all the MCDM tools, considered for assessing the impacts of road intervention. This is because AHP admits the trade-offs between various elements of the assessment process. It elicits the complex judgments of the stakeholders on common grounds and ensures the accuracy of the assessment process based on inconsistency checks built within (Ramanathan, 2001; Singh

et al., 2017). Thus, sufficiently leading to minimization of error induced due to negligence while capturing the judgments of the stakeholders (Kiker et al., 2005). It has been used in environmental decision making, indicator validation for quantitative assessment of environmental and social impacts (Cloquell-Ballester et al., 2006), integrated project evaluation (Dey and Hariharan, 2006), assessing impacts of highway broadening on spatial bio-diversity (Banerjee et al., 2018).

Use of AHP in impact assessment is followed by other tools such as outranking techniques, viz., Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE), and Elimination Et Choix Traduisant la Realite (ELECTRE III). A study by Rogers and Bruen (1998), applied Elimination Et Choix Traduisant la Realite (ELECTRE III) (outranking) MCDM tool to evaluate thresholds of noise impacts of a highway project. Al-Rashdan et al. (1999) employed Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) (outranking) technique to assess environmental impacts of wastewater treatment project. It has been concluded from the study that the methodology employed has been useful in overcoming the problems associated with using various conflicting criteria simultaneously. However, MCDM approaches have been accepted as an effective tool in dealing with impact assessment studies, yet, they have certain shortcomings associated with them, which calls for having more innovative MCDM approaches. Advantages and shortcomings of traditional MCDM approaches have been listed in Table 2.2.

Table 2.2 Advantages and limitations associated with popular MCDM techniques

MCDM method	Advantages	Limitations
Analytic Hierarchy Process (AHP)	Ease of use; scalable; does not need huge data; easily adjustable according to need of decision maker due to its hierarchy structure	Interdependence between indicators and alternatives is the main glitch; may induce inconsistency in the assessment due pair-wise comparison; can lead to rank/weight reversal due to addition or removal of the indicator

Multi-attribute Value Theory (MAVT)	Captures uncertainty to some extent	Needs a huge amount of data, preferences; strong assumptions at every step of the assessment
ELECTRE III	The main advantage is it that it can capture vagueness and uncertainty	Inconvenient from the point of view of explaining the outcomes to the stakeholders; performance of the under-criteria are difficult to identify; difficulty in verifying the results
PROMETHEE	Ease of use; It does not need to follow the assumption that the required criteria are to be compared	Difficulty in assigning of the weights to the criteria, though incomprehensible to identify
Technique for Order Preferences by Similarity to Ideal Solutions (TOPSIS)	Uncomplicated; to use and practicable	Euclidean Distance does not reflect/considers the correlation between indicators; possibility inconsistency may get induce due to addition or removal of the indicator

Source: Compiled from Velasquez and Hester (2013).

Although some of the mentioned techniques can capture the vagueness and uncertainties, still the research needs to focus on formulating the assessment problem more realistically so that it can capture the uncertainty characteristics of both quantitative and qualitative aspects of the assessment simultaneously. Also, there may be another vagueness which needs to be taken care of during the evaluation process, i.e., linguistic judgments (perception of the target population) capture during focus group discussions. Moreover, it becomes more complicated when the assessment is to be performed on a regional scale. Therefore, to deal with such conditions the

concepts of fuzzy set theory can be integrated with MCDM technique, thereby taking care of both types of uncertainties into account with ease (Zadeh, 1978; Ross, 2008). Thus, assisting the researchers in evaluating the impacts of rural road construction with more precision and interpreting the necessary outcomes of the implemented road infrastructure.

There are several fuzzy MCDM techniques which can be employed for performing a comprehensive assessment of the impacts instigated by the construction of rural roads. Methods like fuzzy-TOPSIS, fuzzy Delphi method, fuzzy TOPSIS, and improved fuzzy weighted average method (IFWA), etc. These methods form a strong basis as they can overcome the limitations of conventional MCDM techniques with ease and are cost and time effective. Chen and Hwang (1992) proposed a fuzzy-based TOPSIS technique by transforming the TOPSIS method developed by Hwang and Yoon. Fuzzy-TOPSIS technique-based research has been categorized into different groups, by using the existent approach in integration with other fuzzy based MCDM techniques (Zhang and Lu, 2003), through incorporating hierarchy structure (Kahraman et al., 2007), and through modifications using possibility theory (Ye and Li, 2014). Fuzzy-TOPSIS performs better than other fuzzy based MCDM techniques and does not require complex computations (Junior et al., 2014). The method has been used in various fields like engineering, decision sciences, social sciences, economics, etc. (Kahraman et al., 2015). To add up along with fuzzy-TOPSIS, techniques like fuzzy Delphi method and IFWA also plays a significant role in assessing the impacts of road construction. Fuzzy Delphi overcomes the inconsistency and risks associated with the conventional method and helps in reducing the time and cost associated with the overall questionnaire survey process (Hsu et al., 2010). Though various concepts of fuzzy multi-criteria can be applied for rural road impacts, there is enough scope to develop hybrid methodology by incorporating multivariate analysis and computational intelligence.

In addition to fuzzy MCDM approaches, assessments of impacts can be dealt with efficiently using statistical approaches like multivariate analysis (Vyas and Kumaranayake, 2006). Principal Components Analysis (PCA) is one such technique used for assessing the impacts of rural road construction. This approach provides insightful understanding about various criteria/sub-criteria to be considered for the assessment by in terms of variance. Thus, identifying a concise set of criteria/sub-criteria according to the need for the assessment. Therefore, PCA provides appropriate comprehension about the impacted socio-economic criteria to the concerned policy makers and

planners which will help them to formulate a suitable strategy for achieving sustainable rural development (Devkota et al., 2014).

In the present research, PCA, fuzzy-TOPSIS, fuzzy Delphi, IFWA have been applied as a decision support system to assess the impacts of PMGSY road on the target population.

2.3.4 Computational intelligence approach

Among the new techniques, Computational Intelligence (CI) approach offers factual advantages and are becoming popular, as it can handle complexity associated with the information to be acquired from the data set collected specially to enhance the effectiveness and environmental coherence of transportation system. As each of these techniques is proven as effective when employed. However, when they can be exploited in a symbiotic manner, they prove to be a powerful intelligent decision support system (Akbulut et al., 2004). Adaptive Neuro-Fuzzy Inference System (ANFIS) is one such technique. It is developed by integrating neural networks and fuzzy logic. ANFIS captures the benefits of both neural networks and fuzzy logic and eliminates their shortcomings respectively. ANFIS technique allows in strategic decision making with high-level proficiency in a systematic manner. It is widely used in condition identification (Hosseinlou and Sohrabi, 2009), decision making (Pamučar et al., 2013), prediction modelling (Lee et al., 2015), etc.

It provides results with a tolerance of ambiguity, uncertainty, approximation and handle complex social and human systems comprehensively by utilizing linguistic information in the form of human perception and measured data (Islam et al., 2016), as well as it is time and cost effective. Thus, it is well understood that the ANFIS technique can overcome the existing research shortcomings in the available techniques employed to assess socio-economic impacts thoroughly. It can be a significant value addition to the literature available on socio-economic impacts instigated by road infrastructure.

Thus, from the point of view of sustainable rural development which has been a major concern in developing nations, is achieved through proper assessment, monitoring on the status of scheme/program delivered, and by identifying and mitigating the concerns that arise. It helps to identify the desired outcomes as well as helps to recognize their scope. This study deals with

assessment impacts (positive and negative) instigated by all-weather rural (PMGSY) roads. The study initially focuses on the identification of criteria/sub-criteria that contributes to the change in the socioeconomic status of rural habitation. Further, it concentrates on the assessment of the impacts on five basic attributes, viz., transport facility, income status, education status, health facility, and quality of the neighbourhood (social environment). Next, it also tries to capture the impacts of roads on income diversification as well as it also accounts for the negative impacts instigated. It employs the concepts of mixed-method approaches, fuzzy multiple-attribute decision-making methods, and computational intelligence. Furthermore, it also incorporates GIS application to identify the extent of impacts.

To assess the impacts of rural road construction, an innovative methodology which is divided into four models has been developed. The results have been compared by employing different methods to have refined comprehension. The effectiveness and applicability of the proposed methodology have been demonstrated as a case study of habitations connected by all-weather rural roads in six different blocks of Jhunjhunu district of Rajasthan state of India. Focus group discussions have been conducted for selected habitations to collect necessary data. The data collection has been performed using a questionnaire which has been designed keeping in view with the ground conditions. The questionnaire consists of open-ended questions which enable the enumerators to capture the necessary data/information in a precise way. Moreover, to have refined information feedbacks in the form of satisfaction achieved after the instigations of rural roads has also been considered.

2.4 Existing Research Gap

From the above literature review, it is evident that several research studies have been performed to deal with the identification, assessment, and modeling of impacts instigated by the construction of rural roads. However, a very few field studies have been reported wherein qualitative, quantitative and temporal characteristics of impacts have been assessed simultaneously to assess the scope and status of impacts instigated by road construction at a regional scale. Moreover, these studies lacked to capture the biases arising from the data (i.e., perception of stakeholders and rural inhabitants) extensively, as well as they, have been observed to be costly and time-consuming. It is therefore essential to develop a methodological framework which captures biases of the data

comprehensively and can assess the impacts competently. Therefore, extensive research framework which considers various impacts (positive and negative/direct and indirect) of the rural road will be not only significant but also contributive in taking corrective action plans for improving the quality of life of rural inhabitants, thereby helping concerned decision makers in achieving the intended goal of sustainable rural development.

The assumption which has been considered widely that rural roads are the significant tool which assists in poverty reduction has become explicit imperative. Now it has been strongly recognized that apart from poverty reduction rural roads also instigate other changes in terms of impacts (direct or indirect) on the target population. Since last two decades, several substantial attempts/studies have been made to assess rural road impacts (direct or indirect) using various impact evaluation techniques. These attempts underlined the fundamental difficulties while assessing the extent/scope of the impacts attributable due to the construction of road infrastructure. But common criticism about these road impact assessment studies is they suffer from problems such as endogeneity (Binswanger et al., 1993; Jalan and Ravallion, 1998), inappropriate selection of impact indicators and focus groups, less consideration towards the placement of the road infrastructure to specific region (i.e., in which condition it is allocated). Moreover, estimation of impacts has been biased and not likely robust due unaccountability of various unobserved factors such as data, an appropriate combination of evaluation design and methods.

Therefore, it is essential need to conduct a comprehensive study, which can overcome the existing problems such lack of accuracy and certainty in the data, consideration to quality and quantity aspects. The study should also contribute in devising necessary action plans by involving the inputs from multiple stakeholders. Also, it should be able to consider the uncertainties associated with judgments of experts and concerned decision makers which may cause the imprecise evaluation of the impacts. Moreover, the requirement of information on the scope of impacts also depends upon scientifically acceptable weights considered for each of the indicator corresponding to the assessment process. Therefore, more research is still needed to explore an integrated approach, for assessing impacts of rural road construction by incorporating uncertainty aspects along in consideration with all necessary data, so that it can be handled comprehensively. Thus, fuzzy multi-criteria decision-making framework, computational modeling, and GIS provide a very

strong basis for taking decisions on impact assessment and management, which is lacking at present in the case studies performed in the Indian scenario.

As, there is plenty of scopes to deal with impact assessment methodology as a multifaceted, multi-attribute concept.

2.5 Summary

Many researchers have shown the effectiveness of various quantitative and qualitative techniques to deal with the evaluation of impacts of rural road construction. However, there is enough scope to develop a comprehensive methodological framework using advanced fuzzy based multicriteria decision-making techniques. As they can impart comprehensive understanding about the impacts and provide deeper insights on inherent complexities arising from the biases induced in the data. Also, the application of computational intelligence techniques such as Adaptive Neuro-Fuzzy Inference System (ANFIS) along with Geographical Information Systems (GIS) can enhance the process of evaluation to formulate best management policies. Considering the contemporary practice of impact assessment, application fuzzy multicriteria framework, computational intelligence and GIS has not been explored efficiently. Thus, there is an immediate need to perform adequate research by employing above-techniques in the field of rural road impact evaluation.

The literature review investigations illustrated in this chapter reflects that there is a need for an accelerated pace of research, which can deal with rural road impact assessment studies effectively. The crucial and fundamental findings of the contemporary research include (1) there is a need to develop comprehensive models which not only takes into account the qualitative and quantitative aspects of impacts but also deals with uncertainty aspect associated with the data, (2) developing methodology to assess the status of the impacts instigated by developing cause-effect relationships among various parameters associated with it. Thus, identified shortcomings of the existing research motivate to investigate the impacts induced by the construction of rural roads on the target population, for few selected habitations in Jhunjhunu district of Rajasthan state of India with respect to following aspects:

- To present a systematic and comprehensive models to address the issues related to the identification of various impact indicators/factors that are influenced after the construction of rural roads.

- To know the status of various impacted parameters and to explore their cause-effect relationships, while evaluating overall impacts of road construction for selected roads in Jhunjhunu district of Rajasthan state, so that proper intensification strategy can be suggested to improve their status.

- To deal with uncertainty aspects of stakeholders and impact assessment indicators more effectively by using computational intelligence and advanced fuzzy based multicriteria decision-making techniques and comparing the results with conventional impact assessment methods.

- To explore the change in livelihood activities of the target population due to newly delivered roads, by studying the existing income opportunities and livelihood diversification methods adopted after road construction.

- To highlight the need for assessment of negative impacts along with positive impacts on the scale of the rural neighbourhood as well as to emphasis on the temporal extent of these impacts.

- To emphasize integrating various schemes and policies alongside rural road construction to channelize the resources available to mediate social and economic interests of the target population, by suggesting best action plan and management policies, so that goal of sustainable rural development is achieved.

To provide a suitable solution in the best possible way, a rigorous attempt has been made in the present study by focusing and addressing issues mentioned above using a scientific decision support system.