CHAPTER 3

RESEARCH METHODOLOGY AND RESEARCH METHODS

3.0 Introduction

IR came up with a vision of raising speed of passenger trains on existing tracks to semi-high speed (160-200 kmph), in Dec 2009. Since then, IR has made a number of efforts to raise speed of Bhopal Shatabdi from 150 to 160 kmph on Delhi-Agra route, which is now in the final stages. However, in general there has not been much progress in raising speed of regular passenger trains on major routes as per the vision. The purpose of this study is to identify barriers being faced in realisation of this vision and to analyse them for a better understanding of their complex inter-dependencies to overcome them. Exploratory and descriptive research methodologies have been used for this study. Study began with extensive search and in-depth study of all relevant IR reports on raising speed on existing routes such as white papers and vision documents presented in the Parliament since 2009, budget speeches, feasibility reports of semi-high project of Delhi-Mumbai route, reports published by IRICEN, RDSO and other railway organisations etc. Besides IR reports, papers presented in various national and international seminars and workshops on high speed, presentation etc. were also studied. Articles published in national and international journals on high speed since 2005 have also been studied. Other academic research articles and documents, related to high speed and semi-high speed passenger trains, as available from other sources viz. government publications, websites of various railway systems of the world, national and international journals on railways etc. were also reviewed. Face to face discussions were held with concerned railway expert(s) working in the Ministry of Railways and other railway offices in Delhi. Based on the study and review of relevant literature, various issues and challenges being faced by IR were identified. For finalisation of the issues, discussion with an expert working with IR was conducted. Contextual relationship among such barriers was also discussed with the expert. Thereafter, the inter-relationships among the barriers have been analysed to know the degree of dependence and driving power of each of the barrier and also to understand the pattern (order and direction) of such inter-relationships, through MICMAC (Matrice d'Impacts Croises Multiplication Appliquee a un Classement) and ISM (Interpretive Structural Modelling), with an objective to help policy makers in the formulation of strategy for semi-high speed vision.

3.1 Profile of the Expert

ISM methodology suggests use of expert opinions, based on various management techniques such as brain storming in developing the contextual relationship among the variables under study. The experts of semi-high speed trains are working in various IR institutes/units such as Ministry of Railways, Zonal Railways, IRICEN, Indian Railways Institute of Mechanical, and Electrical Engineers

(IRIMEE), RDSO (Research Designs and Standards Organisation), locomotive and coach production units, RITES and HSRC (High Speed Rail Corporation) etc. Experts working in Railway Board are dealing with policy formulation and those in the Zonal Railways deal with implementation and execution in the field. Experts working in RDSO deal with the design aspects. For the purpose of this study, initially three experts, working at senior levels, were shortlisted one each from the Railway Board, Northern Railway and RDSO for having comprehensive discussion on policy, execution and design issues/barriers of semi-high speed and their contextual inter-relationships. All the three experts were contacted on phone for seeking their time for discussion on the semi-high speed subject. They were also met in person in Delhi (two of them being posted in Delhi and the third one in Lucknow). However, despite repeated efforts, two of the experts from RDSO and NR could not spare time during short period available for the study and finally discussions were held with one of these experts, working in Railway Board, Ministry of Railways, Delhi. This expert has a diverse experience of more than twenty years in IR and has worked on several important positions in various Divisions of Northern Railway and Head Quarter, RDSO and is presently working in the Railway Board, who is responsible for infrastructure planning and development on IR including semi-high speed project.

3.2 Identification and Finalisation of the Barriers

Critical factors emerging from literature review have already been mentioned in the Chapter 2. Based on initial issues identified from the study of literature on the subject, a preliminary round of discussion was held with the expert briefing him about the relevance of the study, research questions, ISM technique for analysis of barriers. During this preliminary exercise, expert was also briefed about the plan and purpose of the discussions with him i.e. to finalise list of barriers to semi-high speed and then to determine contextual relationship among the barriers so finalised. All four kinds of possible relationships among the barriers, as per ISM technique, were explained to him before moving on to this exercise. Thereafter, a questionnaire was prepared and detailed in-depth discussions were held on four occasions. Finalisation of the barriers and contextual relationship among them took two sessions each. Total five rounds of interaction were held with the expert including the preliminary round, over a period of three months from October to January 2015.

Based on literature review, following issues and challenges were identified to be the barriers in raising speed of the passenger trains to semi-high speed (160-200 kmph); (i) non-segregation of passenger and freight trains, (ii) lack of financial resources, (iii) over saturated trunk routes, (iv) non availability of high horse power locomotives, high speed coaches and train sets, (v) rigid organisational structure, (vi) under recovery of cost in passenger business, (vii) inadequately defined mission and objectives, (viii) trespassing on railway tracks, (ix) large number of level crossings, (x) lack of weather monitoring system, (xi) non availability of ATP based signalling system, (xii) non-availability of automatic public announcement system on stations and (xii) non-upgradation of track and bridge infrastructure

Based on discussions with expert, one of the issues identified through literature review i.e. under recovery of cost by IR in passenger business was dropped as in his opinion cost of semi-high speed trains shall be comparable to existing cost of Rajdhani/Shatabdi like train services and thus not a barrier for semi-high speed unlike high speed trains (trains with speed more than 200 kmph) which have significantly high fare structure. Hence, this issue was dropped from the final list of barriers to semi-high speed. During discussions, other issue of non-segregation of passenger and freight services on the existing routes, was found to be a subset of another larger issue of over saturated capacity utilisation on the trunk routes for which IR has to undertake large scale doubling/quadrupling and expeditious execution of DFC projects. Once IR addresses this issue of over saturated line capacity, it would lead to significant segregation of passenger and freight service on most of the trunk routes. Hence, non-segregation of routes for passenger and freight services was also dropped from the list of barriers. Similarly, as per the expert opinion, the two issues of large number of level crossings and non-fencing of tracks have same relationship with all other barriers, both being related to non-protection of existing tracks from trespassing and crossing by stray animals.

Hence, these two barriers were merged together to avoid repetition in the ISM model. Expert opined that there is one more issue which does not feature in the initial list and needs to be addressed for raising speed on existing tracks i.e. lack of public awareness on trespassing/encroachment on railway tracks. Even after fencing and elimination of level crossings, this may continue as a problem for high speed operation if not given due attention. Hence, this issue was added in the list of barriers. The final list of barriers thus finalised after discussion with experts and taken up for further analysis are (i) lack of financial resources, (ii) rigid organisational structure, (iii) inadequately defined mission and objectives, (iv) over saturated trunk routes, (v) lack of high speed locomotives, coaches and train sets, (vi) non upgraded track and bridge infrastructure, (vii) lack of ATP based signalling system, (viii) lack of weather monitoring systems, (ix) lack of public awareness on trespassing/ encroachments on railway tracks, (x) non-availability of automatic public announcement system on stations and (xi) un-protected tracks (large number of level crossings and non-fencing of tracks).

3.3 Interpretive Structural Modelling (ISM)

Interpretive Structural Modelling (ISM), is a methodology developed by Warfield (*Warfield, 1974*) to identify relationship among specific items which define a problem or issue. Warfield used it to analyse complex socio economic systems. Since then, ISM is being extensively used to understand and analyse complex problems and to formulate strategies for their solutions in industry and service sectors such as balancing and sequencing of assembly line, supply chain management, vendor selection, implementation of quality management systems, education and training, manufacturing systems, issues related to productivity and competitiveness etc.

ISM provides an ordered, directional framework for complex problems, and gives decision makers a realistic picture of the situation and the variables involved. It is an interactive learning process in which a set of directly or indirectly related elements are structured into a comprehensive systematic model so as to portray the structure of complex issue or problem in a carefully designed pattern implying graphics as well as words (*Ravi et al, 2005*).

ISM facilitates in bringing order and direction on the complexity of relationships among the variables (*Singh et al., 2003; Jharkharia et al, 2004*).

ISM is a methodology for identifying relationships among specific items which define a problem or an issue (*Sage, 1977*). In complex situations, a number of factors may be related to the problem or issue. ISM helps to understand these relationships. The objectives of ISM in brief are (i) to identify and rank the variables, (ii) to establish inter-relationship among variables and (iii) to discuss managerial implication of research

ISM is intended for use when desired to utilise systematic and logical thinking to approach a complex issue under consideration. ISM is interpretative as the methodology used for finding relationship of different elements is based on decision of the group. The technique is as it extracts an overall structure based on inter-relationship of elements. It is a modelling technique as specific relationship and overall structure are portrayed in a directed graph (a representation of the hierarchical structure of the system) model. It helps to impose order and direction on the complexity of relationships among various elements of a system. It is primarily intended as a group learning process but individuals can also use it.

3.3.1 Steps Involved in ISM

The various steps involved in ISM methodology are as follows:

(i) Identify and list elements affecting the system/relevant to the problem. This could be done by a survey or group problem solving technique.

(ii) Establish contextual relationship between elements with respect to which pairs of elements would be examined.

(iii) Development of Structural self Interaction Matrix (SSIM) for all element. The matrix indicates pair wise relationship among elements of the system.

(iv) Develop Reachability Matrix from SSIM.

(v) Partition the Reachability Matrix into different levels. Convert Reachability Matrix into conical form.

(vi) Draw a directed graph based on relationship given in Reachability Matrix and remove transitive links.

(vii) Convert directed graph into ISM based model by replacing element nodes with the statements.

(viii) Review model to check for conceptual inconsistency and make necessary modifications.

Above steps of ISM modelling have been presented in the Figure 3.1.

3.3.1.1 Structural Self Interaction Matrix (SSIM)

ISM methodology suggests use of opinion of the experts from industry and academics well conversant with the problem under consideration, based on management techniques like brainstorming, nominal group techniques etc., to identify the nature of contextual relationship among the variables. In order to analyse the factors, a contextual relationship of "leads to" or "influences" type must be chosen thereby meaning all factors influence each other. Based on this, contextual relationship between the identified factors is developed. In view of contextual relationship for each factor and relationship between any two factors (*i* and *j*), the associated direction of the relationship is questioned. The following four symbols are used to denote the direction of relationship between two factors (*i* and *j*):

(i) 'V' for the relation from factor i to factor j (factor i influences factor j)

(ii) 'A' for the relation from factor j to factor i (i.e. i is influenced by j)

(iii) 'X' for both direction relations (both i and j influence each other)

(iv) 'O' for no relation between the factors (i.e. i and j are unrelated).

Based on the contextual relationships, an initial SSIM is developed, which is further discussed by a group of experts and based on their response a final SSIM is developed.

3.3.1.2 Reachability Matrix (RM)

The next step is to develop an initial Reachability Matrix from SSIM. For this, SSIM is converted into the initial Reachability Matrix by substituting the four symbols (i.e., V, A, X and O) of SSIM by 1s or 0s in the initial RM. The rules for this substitution are as follows:

(a) If the (*i*, *j*) entry in the SSIM is V, then the (*i*, *j*) entry in the RM is made as 1 and the (*j*, *i*) entry as 0.

(b) If the (*i*, *j*) entry in the SSIM is A, then the (*i*, *j*) entry in the RM is made as 0 and the (*j*, *i*) entry as 1.

(c) If the (*i*, *j*) entry in the SSIM is X, then the (*i*, *j*) entry in the RM is made as 1 and the (*j*, *i*) entry also as 1.

(d) If the (*i*, *j*) entry in the SSIM is O, then the (*i*, *j*) entry in the RM is made as 0 and the (*j*, *i*) entry also as 0.

Following above procedure, an initial RM is prepared. 1* entries are made to incorporate transitivity to fill the gap, if any, in the opinion collected during development of SSIM. After incorporating the transitivity, a final RM is obtained.

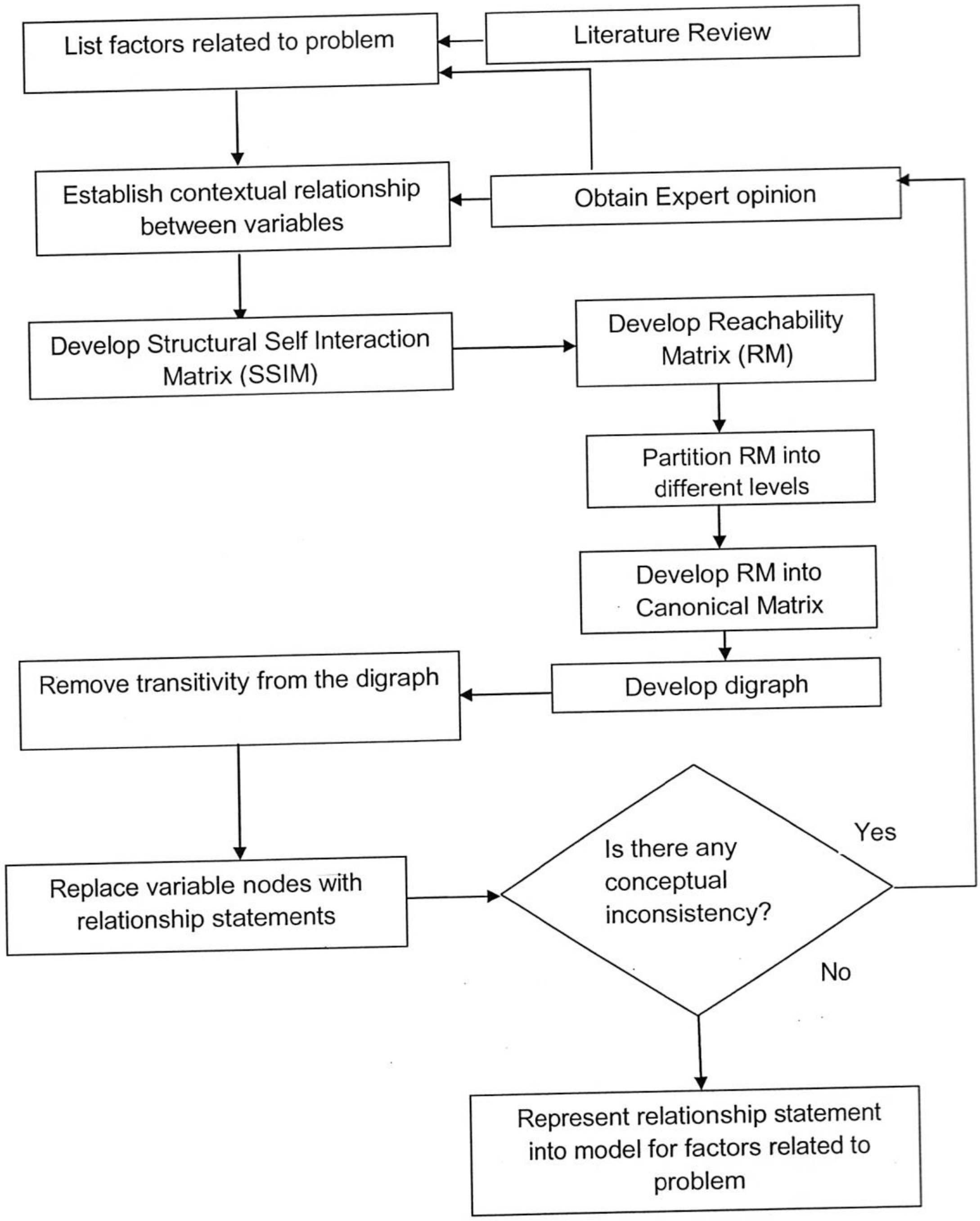

Figure 3.1Flow Diagram for Preparing ISM Model

3.3.1.3 Level Partitions of Reachability Matrix

From the final RM, for each factor, reachability set and antecedent sets are derived. The reachability set consists of the factor itself and the other factor that it may impact, whereas the antecedent set consists of the factor itself and the other factor that may impact it. Thereafter, the intersection of these sets is derived for all the factors and levels of different factor are determined. The factors for which the reachability and the intersection sets are the same occupy the top level in the ISM hierarchy. The top-level factors are those factors that will not lead the other factors above their own level in the hierarchy. Once the top-level factor is identified, it is removed from consideration. Then, the same process is repeated to find out the factors in the next level. This process is continued until the level of each factor is found. These levels help in building the digraph and the ISM model.

3.3.1.4 MICMAC Analysis

The MICMAC means cross-impact matrix multiplication applied to classification and is based on multiplication properties of matrices. The purpose of MICMAC analysis is to identify key variables that drive the system in various categories. In this analysis, based on their driving power and dependency, variables are classified into four categories i.e. autonomous, linkage, dependent and independent (*Mandal et. al, 1994*).

(i) Autonomous Variables: These variables have weak drive power and weak dependence and are relatively disconnected from the system of which they are a part. Such variables have few links with the system, which may be significant.

(ii) Linkage Variables: These are the ones with strong drive power as well as strong dependence. These are relatively unstable as any action on them has an effect on others and also a feedback effect on themselves.

(iii) Dependent Variables: This cluster includes those variables which have weak driver power but strong dependence.

(iv) Independent Variables: These have strong drive power but weak dependence. A variable with a very strong drive power, called key variable, falls into the cluster of independent or linkage variables.

The driver power-dependence matrix gives some valuable insights about the relative importance and interdependencies among critical success factors. The variables with higher driving power are more of the strategic nature. Dependent variables are more towards the performance orientation. Thus, performance can be improved by continuously improving the driver variables (*Singh et. al, 2007*).

3.3.1.5 Canonical Matrix

Canonical matrix is developed by clustering factors in the same level across the rows and columns of the final reachability matrix. The drive power of a factor is derived by summing up the number of ones in the rows and its dependence power by summing up the number of ones in the columns. Now, drive power and dependence power ranks are calculated by giving highest ranks to the factors that have the maximum number of ones in the rows and columns, respectively.

3.3.1.6 Digraph and ISM Model

A digraph is a visual representation of the elements and their interdependencies. From the conical matrix, an initial digraph including transitive links is generated by nodes and lines of edges and a final digraph is obtained by removing the indirect links. The top level factor is positioned at the top of the digraph and second level factor is placed at second position and so on, until the bottom level is placed at the lowest position in the digraph. Once digraph is ready, it is converted into an ISM model by replacing nodes of the factors with statements.

3.3.2 Advantages of ISM

ISM offers several advantages such as:

(i) Systematic – Process can be easily programmed on the computer to consider all possible pair wise relations of system elements, either directly from the responses of the participants or by transitive inference.

(ii) Efficient- Depending on the context, the use of transitive inference may reduce the number of the required relational queries by 50- 80 percent.

(iii) Experts need not have any knowledge of the underlying process. They just need to have enough understanding of the object system to be able to respond to the series of relational queries.

(iv) Guides and records the results of group deliberations on complex issues in an efficient and systematic manner.

(v) Produces a structured model or graphical representation of the original problem situation that can be communicated more effectively to others.

(vi) Enhances the quality of interdisciplinary and interpersonal communication within the context of the problem situation by focusing the attention of the participants on one specific question at a time.

(vii) Encourages issue analysis by allowing participants to explore the adequacy of a proposed list of systems elements or issue statements for illuminating a specified situation.

(viii) Serves as a learning tool by forcing participants to develop a deeper understanding of the meaning and significance of a specified element list and relation.

(ix) Permits action or policy analysis by assisting participants in identifying particular areas for policy action which offer advantages or leverage in pursuing specified objectives.

3.3.3 Limitations of ISM

Complexity of ISM may increase when there are many variable to a problem. Thus, only limited number of variables may be considered in the development of ISM model. Other variables which are least affecting a problem or issue may not be taken in the development of ISM model. Further experts help are taken in analyzing the driving and dependence power of the variable of a problem or issue. These models are not statistically validated. Structural Equation Modelling (SEM), also known as Linear Structural Relationship approach, has the capability of testing the validity of such hypothetical model (*Attri et. al, 2013*).

3.4 Conclusion

Based on literature review and extensive discussions with the expert, eleven variables, considered to be barriers for raising speed of trains on existing tracks to semi-high speed, were identified for analysis through ISM modelling technique. ISM is a very effective tool for understanding inter-relationship of variables effecting complex situations and helps in formulation of strategy for solution. ISM technique uses a systematic process for segregation of issues into various levels of hierarchy depending on contextual relationship of 'leads to' or 'influences' type is chosen between each pair of variable. ISM is simple as it does not require from the user any advanced knowledge of mathematics. While ISM has certain advantages it has some limitations too. It can consider only a limited number of variables for development of ISM model. These models are not statistically validated.