CHAPTER 4

ISM MODELLING OF BARIERS OF SEMI-HIGH SPEED

4.0 Introduction

Various barriers have been identified to raise speed of passenger trains to 160-200 kmph (semi-high speed) on IR based on literature review and opinion of one expert. Literature was reviewed to identify barriers to introduce semi-high speed passenger trains on IR. Brainstorming sessions were held with an IR's expert on semi-high speed project. The eleven identified barriers to introduction of semi-high speed passenger trains on IR are: (i) lack of financial resources, (ii) rigid organisational structure, (iii) inadequately defined mission and objectives, (iv) over saturated trunk routes, (v) non availability of locomotives/coaches/train sets, (vi) non upgraded track and bridge infrastructure, (vii) lack of ATP based signalling system, (viii) lack of weather monitoring system, (ix) lack of public awareness on trespassing and encroachments on railway tracks, (x) non-availability of automatic public announcement system on stations and (xi) unprotected tracks (level crossings and non-fencing). These barriers have been presented in the Table 4.1.

4.1 Discussion on Barriers

4.1.1 Lack of Financial Resources

IR needs massive investment in capacity creation, network expansion and upgradation. Tentative requirement assessed by Vision 2020 document was Rs. 140000 Crore per year for ten year period upto 2019-20. Of this, IR is looking for Gross Budgetary Support of about Rs. 50000 Crore per year from the Government. Tentative fund requirement for track upgradation works alone was Rs. 25000 Crore over ten year period. IR is also not able to generate enough internal resources due to under recovery of cost in its passenger business on account of social obligations. As a result, IR is not getting adequate financial resources to undertake and complete semi-high speed related works.

Table 4.1 Barriers Under Study to Raise Speed of Trains

SN	Barrier Description
1	Lack of financial resources
2	Rigid organisational structure
3	Inadequately defined mission and objectives
4	Over saturated trunk routes
5	Lack of high speed locomotives, coaches and train sets
6	Non upgraded track and bridge infrastructure
7	Lack of ATP based signalling system
8	Lack of weather monitoring systems
9	Lack of public awareness on trespassing/ encroachments on Railway Tracks
10	Non-availability of automatic public announcement system on stations
11	Un-protected tracks (level crossings and non-fencing)

4.1.2 Rigid Organisational Structure

Capacity augmentation works like semi-high speed are large scale projects which require not only massive resources but also face organisational and project execution challenges. Presently, IR is organised on departmental lines such as Civil Engineering, Mechanical Engineering, Electrical Engineering, Signal and Telecom, Stores, Security, Traffic, Accounts and Personnel etc. It is proving increasingly rigid as the competition from road and air transport is heating up and customer expectations are rising. IR needs internal reform through decentralization of decision-making and empowerment of the Railway Zones and Divisions in financial and project execution matters with accountability for results. Reorganization in terms of business lines such as infrastructure, freight, passenger parcel and other auxiliary services is also required to address the issues of improvement in effectiveness and efficiency in achieving goals and building capacity to execute projects within specified time and budget.

4.1.3 Inadequately Defined Mission and Objectives

The vision and mission statements are critical elements of any organizations long term strategy. Organizational mission statements and vision statements serve as guides in development of short term and long term objectives. The objectives thus developed serves as a road map for all the key personnel of the organisation for achievement of vision. A clearly defined mission and objectives helps in efficient and timely execution of all projects especially in a large organisation like IR with 1.3 million staff spread all over the country. While IR has defined its vision for semi-high speed in the "Vision 2020" document, the mission and objectives related to this vision have not been clearly defined. IR still seems to be struggling to enhance speed of one of the Shatabdi trains by just 10 kmph (from 150 to 160 kmph) so as to touch lower most range of semi-high speed band on a short stretch between Delhi-Agra (about 200 km) against its vision of raising speed of regular passenger trains to 160-200 kmph on major trunk routes of IR.

4.1.4 Over Saturated Trunk Routes

The trunk routes of IR which comprise around 16% of network and carry nearly 50 % of the traffic, have already reached over-saturated levels of capacity utilisation. Out of 247 sections on High Density Network, as many as 161 (65%) are running at line capacity utilisation of more than 100% against optimal limit of 80%. Raising speed of passenger trains on these routes without segregation will increase speed differential between passenger and freight trains leading to further reduction in line capacity of already over saturated routes. In order to add line capacity, IR is building DFCs and undertaking construction of new lines and doubling/quadrupling of exiting lines on trunk routes. While two DFCs (Delhi-Mumbai and Delhi-Kolkata) are presently under execution, the work on other two is yet to start and is likely to complete after 2019-20. Similarly, progress of construction of new lines and doubling/quadrupling works are also slow progressing at an average of 600 km and 500 km per year as compared to target of 2500 and 1200 km respectively.

Thus, oversaturated capacity utilisation on trunk routes is a barrier in raising speed of trains and also in achieving necessary segregation of passenger and freight routes without massive rail transport capacity expansion in the country.

4.1.5 Lack of High Speed Locomotives/Coaches/Train Sets

With increase in track capacity for sustaining higher speed, conventional trains with aerodynamically designed higher horse power locomotives and lighter weight coaches or Electric Multiple Unit(EMU)/Diesel Multiple Unit (DMU) train sets are needed to achieve higher acceleration and deceleration to save time in attaining peak speed. Speed potential of rolling stock for safe operation and ride comfort also need to be enhanced commensurate to the higher speed. Present locomotives and coaches are marred with the problem of low acceleration and deceleration for operation at semi-high speed and have maximum permissible speed potential of 160 kmph which is the lowest range of semi-high speed. IR does not have either conventional passenger trains (locomotive hauled) or train sets to meet higher acceleration/deceleration requirement with speed fitness of more than 160 kmph for semi-high speed operation.

4.1.6 Non Upgraded Track and Bridge Infrastructure

Several inputs are needed to upgrade existing tracks and bridges for operation of trains at semi-high speed. IR has stipulated these requirements for train operation at 160 kmph (*Govt. of India, 2009*) Some of the major inputs needed are (i) standard track structure with

60 kg, 90 UTS rails, concrete sleepers and elastic fastenings, (ii) provision of thick web switches on all facing points and swing nose turn outs, (iii) replacement of aluminium thermit welded rail joints with mobile flash butt welded joints, (iv) strengthening of weak bridges and culverts to eliminate permanent speed restrictions on this account, (v) attention to curves for flattening through re-alignment, improving transition, increasing cant and permissible cant deficiency, and (vi) mechanised track maintenance for faster and precise attention to reduce number and duration of temporary speed restrictions.

Slow progress of above activities is posing as a barrier in raising speed of passenger trains to semi-high speed level.

4.1.7 Lack of ATP Based Signalling System

Semi-high speed trains need Automatic Train Protection (ATP) system based advanced signalling systems, such as Train Protection Warning System (TPWS), to ensure safe operation of trains. ATP system based TPWS are in trial operation in Agra-Nizamuddin section. Most of other sections on major trunk routes have either Automatic Block Signalling or Absolute Block Signalling which are barriers in raising speed of trains that need to be overcome to realise the semi-high speed vision on existing tracks.

4.1.8 Lack of Weather Monitoring System

For safety considerations, weather monitoring systems are necessary to avert any disaster in semi-high speed operation of trains on account of bad weather e.g. heavy rainfall, storm, flooding etc. IR presently does not have any weather monitoring system, which is a barrier in raising speed of trains. Water level gauge on each bridge with anemometers and rain gauges at every 30 km interval on routes identified for semi-high speed operation are suggested to be installed to overcome this barrier.

4.1.9 Lack of Public Awareness Regarding Trespassing and Encroachments on Railway Tracks

Trespassing on IR tracks is common due to lack of public awareness as many people do not follow rules and even try to cross a closed level crossing gate. Problem is more acute wherever there is high density of population living along the railway lines. Cattle and pedestrians cross railway lines at many locations endangering safety of high speed trains. It is necessary to address this issue for raising speed of trains to semi-high speed levels to ensure safe operation and prevent losses of human lives.

4.1.10 Non-Availability of Automatic Public Announcement System on Stations

Every station platform on the route of semi-high speed trains needs to be provided with passenger information display and automatic announcement system. This is required for warning passengers waiting on the station platform about passing through semi-high speed train. Present announcement systems are manual and subject to human error. The announcements are required to be made automatically without any need for human intervention, from centralised train control. Automatic announcement becomes necessary as many of the stations' main lines are also serving as platform line. Hence, for raising speed, IR needs to address this barrier.

4.1.11 Un-Protected Tracks (Large Number of Level Crossings and Non-Fencing of Tracks)

There are about 30000 manned and unmanned level crossings on IR network. Level crossings are safety hazards. Trespassing on manned railway crossing is a common sight on all over IR's network. IR needs to eliminate all level crossings, on the routes identified for semi-high speed operation, by building ROB/RUBs or Low Height Subways to overcome this barrier.

IR does not have protection fences on railway tracks to prevent trespass by human beings and animals. "Cattle run over" by trains is a common feature for IR. IR also does not have provision of platform fences for safety of people on platform. Tracks lying on routes identified for semi-high speed train operation are required to be fenced to overcome this barrier.

4.2 Development of ISM Model

The ISM methodology, described in Chapter 3, has been used to model the barriers in raising speed of trains to semi-high speed to understand relationship among them for better and faster execution of related projects.

The process starts with the identification of barriers to the problem using group solving techniques. In the next stage, a contextually relevant subordinate relation is chosen based on which SSIM is developed. In the next step SSIM is converted into a reachability matrix. Finally, elements are partitioned into various levels and converted into a structural model. In modelling barriers to raise speed on IR, the following steps have been considered.

Step 1: Barriers of semi-high speed are listed, which have been identified based on literature review and discussions with expert.

Step 2: A contextual relationship is established among the variables identified in Step 1.

Step 3: A Structural Self-Interaction Matrix (SSIM) is developed for barriers which indicates pair-wise relationships among the variables (barriers).

Step 4: Reachability matrix is developed from SSIM.

Step 5: The reachability matrix obtained in Step 4 is partitioned into different levels.

Step 6: Based on the relationships given in the reachability matrix, a directed graph (digraph) is drawn and the transitivities are removed. The transitivity of the contextual relation indicates that if variable A is related to B and B is related to C, then A is related to C.

Step 7: The resultant digraph is converted into an ISM, by replacing variable nodes with statements.

Step 8: The ISM model developed in Step 7 is reviewed to check for conceptual inconsistency and necessary modifications are made.

4.2.1 Structured Self Interaction Matrix (SSIM) of Barriers

As per ISM methodology, opinion of an expert has been used in developing the contextual relationship among the variables through extensive discussions on each element. In order to analyze the relationship among the barriers a contextual relationship of "leads to" type is chosen. The following symbols are used to denote the direction of relationship between barriers (i and j) to analyse the barriers in developing SSIM.

1. V Barrier i will help to alleviate barrier j
2. A Barrier j will help to alleviated barrier i;
3. X Barriers i and j will help alleviate each other
4. O Barriers i and j are unrelated.

The following statements explain the use of symbols V, A, X and O for barriers in SSIM as depicted in Table 4.2.

(i) Barrier 1 helps to alleviate barrier 4. It implies that if an effort is made to find financial resources then it would help IR in expanding its line capacity on over saturated routes through faster execution of works related to doubling/quadrupling of line, new lines, DFC etc. It would help generate capacity for segregation of passenger and freight trains that are necessary for induction of semi-high speed trains on existing trunk routes. Hence, 'V' in Table 4.2 denotes the relationship between 1 and 4.

(ii) Barrier 3 can help alleviate barrier 1 i.e. having a clearly defined mission and objective for the semi-high speed vision will lay a detailed time bound road map for the planners as well executors, belonging to different departments, and help in timely sourcing and sanction of funds for semi-high speed projects. Thus, 'A' denotes the the relationship between barriers 1 and 3 in SSIM as exhibited in Table 4.2.

(iii) Barrier 6 and 7 help alleviate each other. Upgradation of tracks and bridges will help in execution of signal works that are laid along the track. Similarly, upgradation of signalling system will help in upgradation of tracks. Thus, 'X' denotes the relationship between these two variables in SSIM as shown in Table 4.2.

(iv) No relationship exists between barrier 1 (lack of financial resources) and 2 (rigid organisational structure), as lack of financial resources is entirely due to less budgetary support from the government and low generation of internal resources and extra budgetary sources has got no link with rigid organisational structure which is effecting project execution efficiency. Thus, 'O' denotes the relationship between barrier 1 and 2 in Table 4.2.

Table 4.2 Structural Self Interaction (SSIM) of Barriers Under Study

SN	Barrier Description	Barrier Number									
		11	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**
1	Lack of Financial Resources	V	V	O	V	V	V	V	V	A	O
2	Rigid Organisational Structure	O	O	O	O	V	V	V	O	O	X
3	Inadequately defined Mission and Objectives	V	V	O	V	V	V	V	V	X	
4	Over Saturated Trunk Routes	O	O	O	O	O	O	O	X		
5	Lack of High Speed Locomotives, coaches and train sets	O	O	O	O	O	O	X			
6	Non Upgraded Track and Bridge Infrastructure	O	O	O	O	X	X				
7	Lack of ATP based Signalling System	O	V	O	O	X					
8	Lack of Weather Monitoring Systems	O	O	O	X						
9	Lack of public awareness on trespassing/ encroachments on Railway Tracks	A	A	X							
10	Non-availability of Automatic Public Announcement System on Stations	O	X								
11	Unprotected tracks (Level crossing and non fencing)	X									

4.2.2 Reachability Matrix of Barriers

The SSIM is converted into a binary initial reachability matrix by substituting V, A, X and O by 1 and 0 as per following rules:

1. If the (i, j) entry in the SSIM is V, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 0.

2. If the (i, j) entry in the SSIM is A, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 1.
3. If the (i, j) entry in the SSIM is X, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry also becomes 1.
4. If the (i, j) entry in the SSIM is O, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry also becomes 0.

Following the above mentioned rules, initial reachability matrix for barriers is created in Table 4.3. Thereafter, final reachability matrix is drawn in Table 4.4, by incorporating the transitivities (indicated as 1*) as described in the ISM methodology. 'Driving power' and 'dependence' of each individual barrier has also been shown in this matrix. The driving power of a variable is total number of variables (including itself) which it may help achieve. Dependence is the total number of variables which may help achieving it. For example, barrier 3 (inadequately defined mission and objectives) has maximum driving power of 10 and barrier 4 (over saturated trunk routes), barrier 5 (lack of high speed locomotives, coaches and train sets), barrier 8 (lack of weather monitoring system) and barrier 9 (lack of public awareness on trespassing/encroachment on tracks) have the least driving power of 1 among all the variables. Similarly, barrier 6 (non upgraded track and bridge infrastructure) and barrier 7 (lack of ATP based signalling system) have maximum dependence of 5 and barrier 2 (rigid organisational structure) and barrier 3 (inadequately defined mission and objective) are having least dependence of 1.

Table 4.3 – Initial Reachability Matrix for Barriers Under Study

SN	Barrier Description	Barrier Number										
		1	2	3	4	5	6	7	8	9	10	11
1	Lack of Financial Resources	1	0	0	1	1	1	1	1	0	1	1
2	Rigid Organisational Structure	0	1	0	0	1	1	1	0	0	0	0
3	Inadequately defined Mission and Objectives	1	0	1	1	1	1	1	1	0	1	1
4	Over Saturated Trunk Routes	0	0	0	1	0	0	0	0	0	0	0
5	Lack of high speed locomotives, coaches and train sets	0	0	0	0	1	0	0	0	0	0	0
6	Non Upgraded Track and Bridge Infrastructure	0	0	0	0	0	1	1	0	0	0	0
7	Lack of Automatic Train Protection Signalling System	0	0	0	0	0	1	1	0	0	1	0
8	Lack of Weather Monitoring Systems	0	0	0	0	0	0	0	1	0	0	0
9	Lack of public awareness on trespassing/ encroachments on Railway Tracks	0	0	0	0	0	0	0	0	1	0	0
10	Non-availability of Automatic Public Announcement System on Stations	0	0	0	0	0	0	0	0	1	1	0
11	Unprotected tracks (Level crossing and non fencing)	0	0	0	0	0	0	0	0	1	0	1

Table 4.4 – Final Reachability Matrix for Barriers Under Study

SN	Barrier Description	Barrier Number											DP*
		1	2	3	4	5	6	7	8	9	10	11	
1	Lack of Financial Resources	1	0	0	1	1	1	1	1	1*	1	1	9
2	Rigid Organisational Structure	0	1	0	0	1	1	1	0	0	1*	0	5
3	Inadequately defined Mission and Objectives	1	0	1	1	1	1	1	1	1*	1	1	10
4	Over Saturated Trunk Routes	0	0	0	1	0	0	0	0	0	0	0	1
5	Lack of high speed locomotives, coaches and train sets	0	0	0	0	1	0	0	0	0	0	0	1
6	Non Upgraded Track and Bridge Infrastructure	0	0	0	0	0	1	1	0	0	1*	0	3
7	Lack of ATP Based Signalling System	0	0	0	0	0	1	1	0	1*	1	0	4
8	Lack of Weather Monitoring Systems	0	0	0	0	0	0	0	1	0	0	0	1
9	Lack of public awareness on trespassing/ encroachments on Railway Tracks	0	0	0	0	0	0	0	0	1	0	0	1
10	Non-availability of Automatic Public Announcement System on Stations	0	0	0	0	0	0	0	0	1	1	0	2
11	Unprotected tracks (Level crossing and non fencing)	0	0	0	0	0	0	0	0	1	0	1	2
	Dependence	2	1	1	3	4	5	5	3	6	6	3	39

* DP = Driving Power

4.2.3 Level Partitions of Reachability Matrix

The reachability and antecedent sets (Warfield, 1976) for each variable are obtained from final reachability matrix. The reachability set for a particular variable consists of the variable itself and the other variables, which it may help achieve. The antecedent set consists of the variable itself and the other variables, which may help in achieving them. Subsequently, the intersection of these sets is derived for all variables. The variable for which the reachability and the intersection sets are the same is assigned as the top-level variable in the ISM hierarchy as it would not help achieve any other variable above their own level. After the identification of the top-level element, it is discarded from the list of remaining variables.

From Table 4.4 it can be seen that barrier 4, 5, 8 and 9 e.g. over saturated trunk routes, lack of high speed locomotives, coaches and train sets, lack of weather monitoring system and lack of public awareness on trespassing/encroachments on railway tracks are at level 1 thereby meaning that these barriers shall be placed at the top of the ISM hierarchy. This iteration is repeated to obtain successive levels for each of the variable. Barriers 10 and 11 are placed at level 2, barriers 6 and 7 at the next level 3, barriers 1 and 2 at the level 4 and barrier 3 at the last most important bottom level barrier at level 5.

Table 4.5 Partition of Reachability Matrix for Barriers Under Study

First Iteration

Barrier No.	Reachability Set	Antecedent Set	Intersection Set	Level
1	1,4,5,6,7,8,9,10,11	1,3	1	
2	2,5,6,7,10	2	2	
3	1, 3, 4, 5, 6, 7, 8, 9, 10,11	3	3	
4	4	1, 3, 4	4	Level 1
5	5	1, 2, 3, 5	5	Level 1
6	6, 7, 10	1, 2, 3, 6, 7	6, 7	
7	6, 7, 9, 10	1, 2, 3, 6, 7	6, 7	
8	8	1, 3, 8	8	Level 1
9	9	1, 3, 7, 9, 10, 11	9	Level 1
10	9, 10	1, 2, 3, 6, 7, 10	10	
11	9, 11	1, 3, 11	11	

Second Iteration

Barrier No.	Reachability Set	Antecedent Set	Intersection Set	Level
1	1, 6, 7, 10, 11	1,3	1	
2	2, ,6, 7, 10	2	2	
3	1, 3, 6, 7, 10,11	3	3	
6	6, 7, 10	1, 2, 3, 6, 7	6, 7	
7	6, 7, 10	1, 2, 3, 6, 7	6, 7	
10	10	1, 2, 3, 6, 7, 10	10	Level 2
11	11	1, 3, 11	11	Level 2

Third Iteration

Barrier No.	Reachability Set	Antecedent Set	Intersection Set	Level
1	1, 6, 7	1,3	1	
2	2, 6, 7	2	2	
3	1, 3, 6, 7	3	3	
6	6, 7	1, 2, 3, 6, 7	6, 7	Level 3
7	6, 7	1, 2, 3, 6, 7	6, 7	Level 3

Fourth Iteration

Barrier No.	Reachability Set	Antecedent Set	Intersection Set	Level
1	1	1,3	1	Level 4
2	2	2	2	Level 4
3	1, 3	3	3	Level 5

4.2.4 ISM Model Formulation

The levels found through partitioning of final reachability matrix and various barriers at these levels have been summarised in the Table 4.5. From the final reachability matrix and partitioned levels, a structural model is generated. If the relationship exists between barriers i and j, an arrow pointing from i to j is used to depict the same. The resultant graph is called directed graph or in short digraph. The digraphs before removing the transitivities and after removing the same have been shown in Figure 4.1 and 4.2 respectively. The ISM model for barriers of semi-high speed has been shown in Figure 4.3.

Table 4.6 Various Levels of Barriers of Semi-High Speed

Level No.	Barrier No.	Barrier Description
1st	4	Over Saturated Trunk Routes
	5	Lack of high speed locomotives, coaches and train sets
	8	Lack of weather monitoring systems
	9	Lack of public awareness on trespassing/ encroachments on Railway Tracks
2nd	10	Non-availability of Automatic Public Announcement System on Stations
	11	Trespassing on tracks (Level crossing and non fencing)
3rd	6	Non Upgraded Track and Bridge Infrastructure
	7	Lack of ATP Based Signal System
4th	1	Lack of Financial Resources
	2	Rigid Organisational Structure
5th	3	Inadequately defined Mission and Objectives

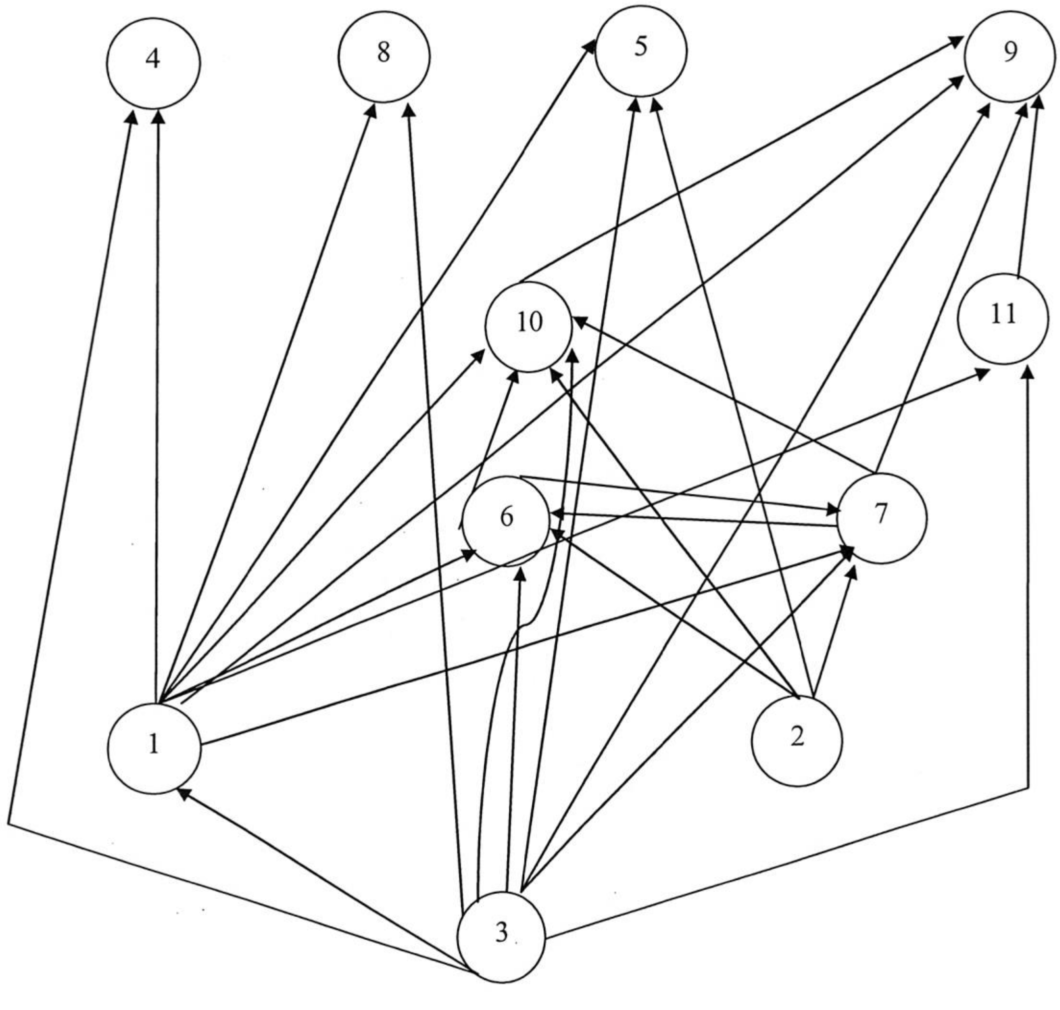

Figure 4.2 Digraph Before Removing the Transitivities of the Barriers

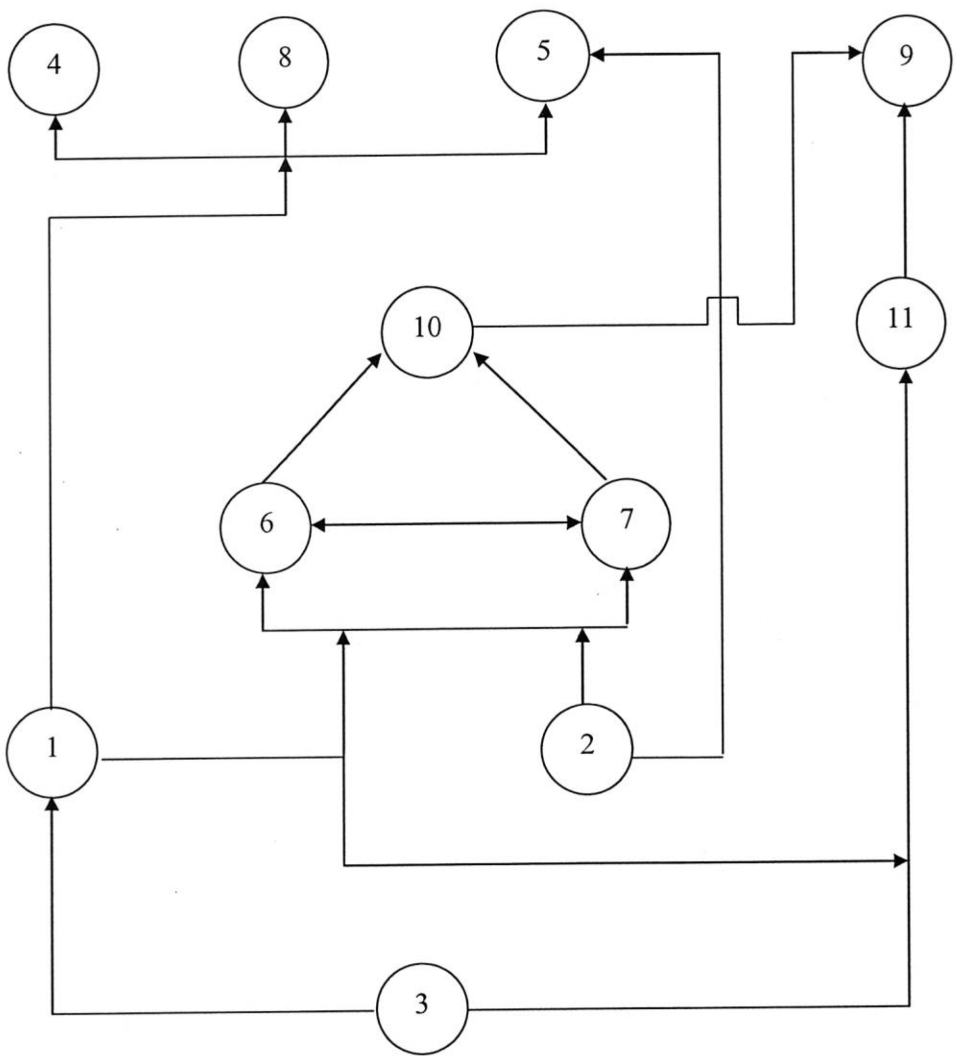

Figure 4.2 Digraph After Removing the Transitivities of the Barriers

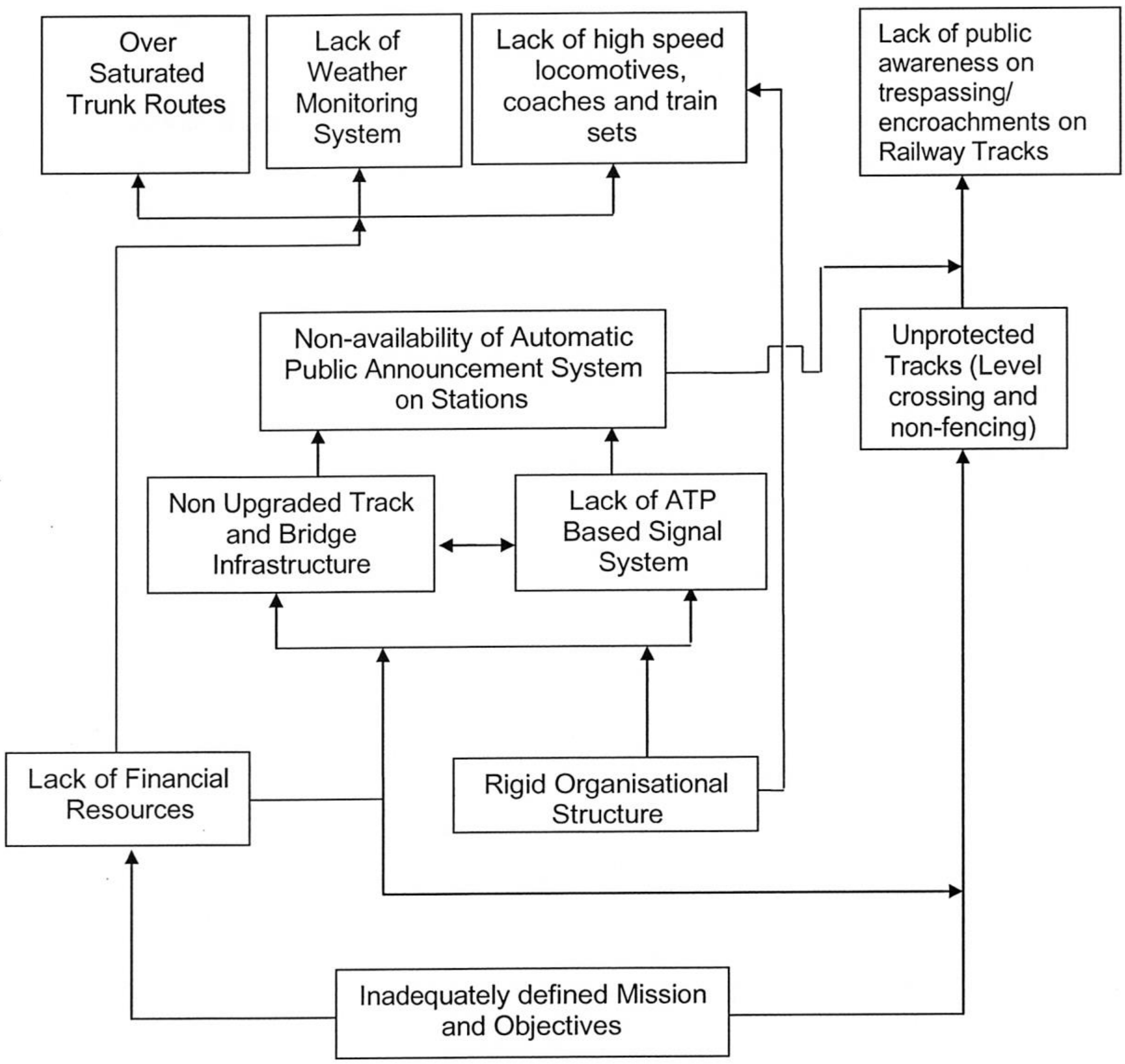

Figure 4.3 ISM Based Model for the Barriers of Semi-High Speed

4.3 MICMAC Analysis

The purpose of MICMAC analysis is to analyse the driving power and dependency of the barriers to semi-high speed on the existing tracks. Based on their driving power and dependence, barriers have been classified into four clusters viz. autonomous, linkage, dependent and driver variables.

Figure 4.4 presents distribution of all barriers under study. Driving power is represented on Y-axis and dependence on the X-axis. As an illustration barrier 1 (lack of financial resources) has dependence of 2 and driving power of 9. Hence it has been placed in the fourth cluster of independent variables with high driving power and low dependence.

In this study, there are seven autonomous barriers i.e. barrier number 2 (rigid organisational structure), barrier number 4 (over saturated trunk routes), barrier number 5 (lack of high speed locomotives, coaches and train sets), barrier number 6 (non-upgraded track and bridge infrastructure), barrier number 7 (lack of ATP based signalling system), barrier number 8 (lack of weather monitoring system) and barrier number 11 (unprotected tracks – large number of level crossings and non fencing of tracks). These barriers have few links, some of which are significant.

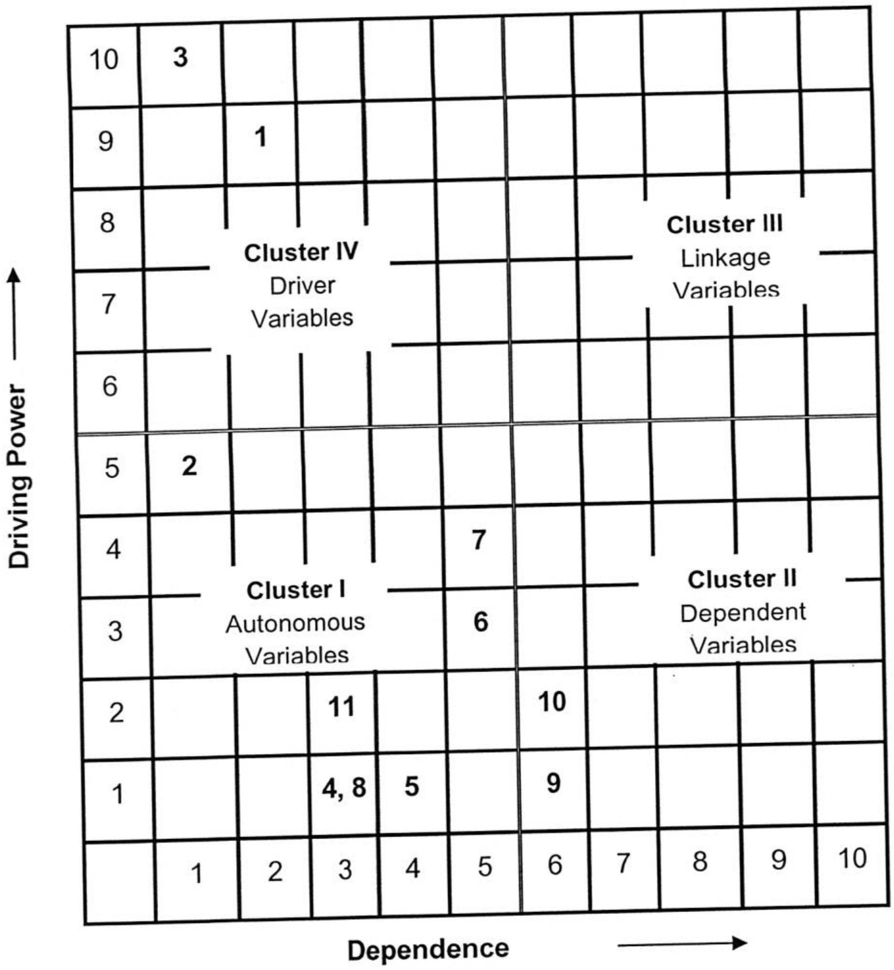

Figure 4.4 MICMAC Analysis

The second cluster of dependent variables has two barriers i.e. barrier number 9 (Lack of public awareness on trespassing/encroachments on railway tracks) and barrier number 10 (non availability of automatic public announcement system on stations). Both these barriers have weak driving power but strong dependence.

The third cluster of variables with strong driving power and a strong dependence has no barriers in this study. Fourth cluster of independent (driver) variables, with high driving power and low dependence, has two barriers; barrier number 1 (lack of financial resources) and barrier number 3 (inadequately defined mission and objectives). The barrier number 3 i.e. inadequately defined mission and objective is the key variable with a very strong driving power.

4.4 Discussion on ISM Model for the Barriers

ISM model for barriers of semi-high speed, as depicted in Figure 4.3, indicates that barrier number 3 (inadequately defined mission and objectives) is the key barrier at the base of the hierarchy. This barrier is also the key driver as per MICMAC analysis with very low dependence. The barriers at the next higher level are barrier number 1 (lack of financial resources) and barrier number 2 (rigid organisational structure). All these three barriers are related to strategy and impact other barriers. In order to raise speed on existing tracks in the most effective and time bound manner, barriers viz. barrier number 3 (inadequately defined mission and objectives) and barrier number 1 (lack of financial resources) need to be addressed first. Addressing the barrier number 3 (inadequately defined mission and objectives) in strategic category would help in expediting project based elements of semi-high speed such as upgradation of track, signalling and rolling stock infrastructure.

Barriers like barrier number 4 (oversaturated trunk routes), barrier number 8 (lack of weather monitoring system), and barrier number 5 (lack of high speed locomotives, coaches and train sets) are on the top of the hierarchy with very few linkages with any other variables.

These can be addressed relatively easily as compared to other barriers, once strategic barriers are addressed. Barrier number 9 (lack of public awareness on trespassing/encroachments on railway tracks) is another barrier on the top most level of hierarchy. This can be addressed more effectively, once besides strategic barriers other barriers in the hierarchy related to deficiencies in track and signalling infrastructure, automatic announcement system on stations, removal of level crossings and fencing of tracks are also addressed. These are performance and operating level elements.

Barrier number 6 (non upgraded tracks and bridge infrastructure) and barrier number 7 (lack of ATP based signalling) are two barriers which are impacting each other. Both of these are operational level barriers interdependent on each other. Addressing track and signalling barriers will help to address barrier at the next higher level viz. Barrier number 10 (non availability of automatic public announcement system on stations) as it works on inputs from advanced signalling and traffic control systems.

The barrier number 11 (unprotected tracks, large number of level crossings and non fencing of tracks), appears at second top most level in the ISM hierarchy. Addressing strategic barriers of inadequately defined mission and objectives and lack of financial resources will help in overcoming this barrier. Protection of tracks by elimination of level crossing and fencing will help in achieving next level barrier of lack of public awareness on trespassing/encroachments on railway tracks.

Barrier number 2 (rigid organisational structure) appears at second level from the bottom in ISM hierarchy thereby meaning that it is an important barrier. However, unlike all other barriers, it is not dependent on strategic issues i.e. inadequately defined mission and objectives and lack of financial resources. But it has power to driver other operating and performance level barriers.

4.5 Conclusion

The analysis of barriers through ISM modelling suggests that there is need to clearly define mission and objectives related to IR's vision of semi-high speed on major trunk routes by 2020 such that there is a clear road map for guidance and adherence by all concerned employees. There is also a very strong need for arranging necessary financial resources to accomplish this vision. Restructuring the organisation would help in overcoming other barriers more effectively. Issues like high speed locomotives, coaches and train sets, expansion of track capacity for segregation of passenger and freight traffic, weather monitoring system and improving public awareness on trespassing/encroachments on railway tracks can be taken up immediately as these are having a significant impact on other barriers.