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Optimization of Critical Factors of Northern Railway Network using TISM and DEMATEL

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Abstract: ***The Indian railway network is one of the largest rail networks that undergo continuous expansion. However, more reliable and safe service in-network is subject of growing attention in India but to work on these challenges is a cumbersome task as each factor is influencing each other. Studying these parameters is tedious task and will contribute significantly to improving the operations and overall management of railway network. The purpose of this research study is to identify and optimize different vulnerable factors that are affecting smooth functioning of railway network through identification of hierarchical correlations among parameters and prioritizing performing a specific order for identification and improvement. Thus keeping in mind the perspective the research is based on an integrated approach of DEMATEL (Decision-making trial and evaluation laboratory) and TISM (Total interpretative structural modeling). Based on extensive review of literature and expert opinion, 15 vulnerable parameters were identified and expert elicitation was applied to determine correlation among factors. The scope of this research suggests that five layers structural model can be formed. Network layout and emergency measure during disaster held maximum weight and individual workload, stress, and different environmental conditions were independent factors inclined at lower levels. The research provides reliable information for decision-makers to form active strategies and management policies for more adequate and reliable system of network. Also more safe and profitable network that will promote sustainable development throughout India. This study provides more efficient, efficacious, robust and systematic way to surmount challenges.***

Keywords: ***Challenges, DEMATEL, Railway Network Factor Analysis, Reliability, TISM.***

I. INTRODUCTION

Every organization endeavors to enhance its productivity and always in search of tools that on implementation present limited resources and derives the best output. The study aims to deliver a simple model which when employed in India Railways, eight largest employers of world, helps in smoothening its workflow, enhancing its reliability and availability.

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Indian Railways is the fourth-largest rail network and runs 20,000 passenger trains and 9200 trains in freight segment daily. Due to its imperative nature, the economic budget of the fiscal year 2019-20 of Indian government gave a budgetary allocation of ₹ 65,837 crore. The data displays the importance of this organization on daily economic, social affairs of the country and the demand for high reliability. The complex large scale organization on which relies the functioning of a vast section of the country faces disruptions, irregularities, failures. Locomotive failure is one of the most challenging and hindering tasks to the Indian Railways aiming for the smooth running of its trains around the country. Daily at an average, more than five locomotives are failed in between their journey, leading to chaos and congestion in the route and ultimately leading to heavy traffic block. Hence, there is an urgent need to analyze the functioning of the organization to reduce the cases of failures. The analyze will consider not only the technical faults of locomotives but also the functioning failures which are driven by factors such as Individual technical capability, organizational structure, network topology, safety investment, education and training, emergency management plan, operating environment, rules and regulations, individual workload and stress.

The research study attempt is to organize the complex network of the organization into a structured form, which is explicit and understandable also, which helps us to know the inter-relationship and inter-dependency of various factors. We have used an integrated approach of Decision-Making Trail Evolution Laboratory (DEMATEL) and total interpretative structural modeling (TISM) for creating a conceptual model with correlated parameters that are prioritized using DEMATEL. The MICMAC analysis done at later stages which are based on multiplication property of matrices graphically represents the interconnection, driving and dependence power by forming clusters of all the factors into four categories- Quadrant 1 represents autonomous variable, Quadrant 2 shows the dependent variables, Quadrant 3 represents linkage variables and Quadrant 4 shows independent variables, which are also called as driver variables.

II. LITERATURE REVIEW

Considerable studies have researched the biggest network of railways in the world that is the Indian railway network and analyzed those using different approaches. These studies have been discussed below briefly. Awadhesh et al. (2013) in their study stepped towards a strategic analysis of reliability and scientific management of diesel locomotives in Indian railways.

The failure analysis to done to locate critical components in the diesel locomotive system, to establish a uniform understanding and practically useful approach for system record, failure database and strategic analysis of failures. The paper considered a basic theory of Pareto's principle of scientific management for a detailed analysis of locomotive systems failure data.

It recommends an ideal system of recording of line failures, computerization of failure database and it suggests three levels of recording i.e. reporting, investigation and assessment. Besides, it recommends a hierarchical system of analysis of failures for better strategy and decision-making. The findings of this paper should be applied to the Indian railways' system for better disposal of failures, to know the root cause of failure and to minimize the failure cases. This strategy can be applied to other industries as well.

Jena et al (2016) studies critical success parameters for smartphone manufacturing industries ecosystem in India using TISM modelling for 15 critical factors in smartphone industry to develop a conceptual framework for different critical factors and develop relationships among them. Results can be used to promote framework in smartphone manufacturing in India. Further cab be explored and assessed to improve the drivers of framework.

Rade et al. (2017) worked on the ISM method in a system of hot dyeing waste slurry. In his study, he computed vulnerable factors that will affect the rate of heat transfer of hot dyeing waste slurry and ISM model created for them to identify their interdependence and estimate the level of significance on each other. He also mentioned that ISM is a part of the soft operation research family. It is an approach for simplifying complex relationships among various elements of a complex system by creating a simple clear structure, map, and graph. It uses practical knowledge of experts to decompose the structure and create a multilevel structural model. Kunar et al. (2013) presented a study intending to analyze the reliability by using Weibull distribution, various data plots, and failure rate information to determine results that can be utilized by railway locomotive engines for a reduction in unexpected breakdowns and to enhance the reliability and availability of engine. The objective of his study was to determine the reliability, availability and maintainability aspects of the two most significant constituent of railway diesel locomotive engine i.e. Power pack assemblies, Engine System. A broad study is done to gather accurate data at a suitable level of detail for availability analysis. For maintenance of spare part inventory, the ABC analysis was done. Weibull Distribution was used for reliability analysis. The RAM measurement and evaluation of diesel locomotive engine helps in bringing down the unexpected breakdowns and to minimize the expenditure on maintenance. He also concluded that this study is useful in future for other industries as well to minimize the breakdown of machines, to effectively apply predictive and preventive maintenance which can help in cost reduction as well.

Sayali et al. (2014) suggested a way to improve productivity in industry by using TISM that helps in managing complexity, determination of various factors, their interdependence, and driven, driving capacity. As every organization focus on its productivity, that is a representation of the effective and efficient conversion of resources into marketable products. His study focused on improving the productivity of the construction industry by using TISM. This methodology gave a systematic relationship between the factors affecting labor productivity.

Rajesh et al. (2013) in his work tried to develop a method that helps in identifying a structure and interpreting a model in a complex system for the ease of identifying relations between various components, elements that can be utilized further research. He gave an overview of the interpretive structural modeling ISM approach. He used the systematic application of basic concepts of graph theory and Boolean algebra that on implementation in a human-computer interaction utilized the theoretical, conceptual and computational advantage to construct a directed graph that is a representation of the hierarchical structure of a system.

The above method had two advantages i.e. advance mathematical knowledge viewpoint and efficiency in terms of economizing computer time. He concluded that the method can be used in the field of process design, career planning, strategic planning, engineering problems, product design, process re-engineering, complex technical problems, financial decision making, human resources, competitive analysis and electronic commerce to process and structure details and establish relationship among various components and their interdependence for better analysis purpose. In addition, he mentioned that the ISM process fixes the unclear, poorly organized mental models into well-defined and structured models that can help to find the key factor that can create issues or problems that can be used for strategy development for the eradication of certain issues or problems.

Maciej et al. (2014) focused his study to analyses a particular model of a diesel locomotive, the objective was to evaluate the reliability, availability, and maintenance of SM48 diesel locomotive, which was a locomotive sample of Polish rail company PKP CARGO S.A. The operational data was analyzed to calculate the reliability, availability, and maintainability, the tests and analysis of wear and tear of locomotive assembly provided the basis for modification and enhancement of the locomotive maintenance cycle. The reliability ratios that are determined in his study can also form the basis for a Life Cycle Cost (LCC) analysis.

Liangliang et al. (2017) worked on a research to use the AHP and ISM to perform a quantitative analysis of vulnerability factors to provide quality information that can be used to take proactive strategies and guarantee the safety operation of an urban rail transit system. The study tried to explore the vulnerability factors based on an integrated method consisting of AHP (Analytical Hierarchy Process) and ISM (Interpretative Structural Modeling). This study focuses on exploring the global system vulnerability where vulnerability means susceptibility to injury or attack. It is the manifestation of the inherent states of the system that express the extent of adverse effects caused by disruptive events that originate both within and outside the system boundary. The methodology used in this study is an integrated approach of AHP and ISM for better understanding of 21 vulnerability factors.

The AHP is used to assign a weight to each vulnerability factor and evaluate their relative importance while ISM is used to describe the interdependence among these factors This new technique is better than conventional safety analysis and makes the result more subjective. It allows the production of new perception into elevating the safety of urban rail transit operations.

The integrated method makes the extraction possess superior credibility. The study provides useful insight and knowledge of safety operation of the urban rail transit system and the calculated factors should be formulated which can prove to be a safer and reliable option. In this paper for the sake of simplicity AHP method was applied however, it is encouraged to use ANP method for future research purposes.

Mordin et al. (2015) worked on a project that aims to establish an evaluation method that can be applied in the railway system for excellent RAM performance. The objective of the study was to establish a method that can either decrease the occurrence of root causes or increase the detectability of failure. Also to evaluate the reliability, to determine the effect of availability and maintainability of train operation using RAMS analysis and to find the best concept of RAMS engineering to provide guidelines on how these concepts can be implemented to improve the RAMS of a diesel locomotive. The reliability of the system was done by qualitative and quantitative methods. FMEA and FTA were used in qualitative analysis and the quantitative method is used to measure the amounts of reliability, availability, and maintainability of the system, based on MTBF and MTTR of different components of the system. The proposed assessment methods were applied and investigation on the RAMS performance was done to analyses the failure cause. Also, suggestions to improve system reliability based on the FTA model were introduced.

Table- I: Vulnerable Parameters for Northern Indian Railway network

Parameters	Description	References
Individual technical capability (F1)	Technical capacity of individuals known as skills, knowledge, and experience of individual. A capable employee can handle situations with relatively fewer mistakes.	Awadhesh et al. (2013), Burton et al. (2001)
Individual workload and stress (F2)	Individuals work and stress is directly related to the performance of employee	Szkoda et al. (2016), Jena et. al (2016)
Equipment/facility condition (F3)	The Facility and Equipment condition is very prominent for optimum output.	Ghosh et. al (2013)
Equipment/facility performance (F4)	Facility and Equipment performance is a variable of reliable technologies and advanced materials for the railway network.	Botre et. al (2014), Jena et. al (2016)
Equipment/facility protection (F5)	Protection is a major issue for the reliability of any Plant / Equipment as better security for passenger and better Equipment is necessary for any company and network.	Rade et. al (2017)
Natural environment (F6)	It is evident to avoid natural disaster-prone areas for railway Facilities or networks as it can disrupt the working of Railways.	Awadhesh et al. (2013)
Social environment (F7)	Employee's education and training are very important as it improves operational capability as well as work as experience for new recruits and staffs.	Ghosh et. al (2013)
Operating environment (F8)	Operation condition means the working condition of Railway diesel sheds as well as the travel environment for passengers.	Szkoda et al. (2016)
Safety investment (F9)	Indian railways invest a substantial amount for safety as any disaster or damage causes huge amount for repairs.	Isha et.al (2015), Ping et. al (2017)
Education and training (F10)	Social conditions refer to employee's connectivity with each other and for passenger social conditions of facility.	Jena et. al (2016)
Rules and Regulations (F11)	Rules and regulations are important for the smooth functioning of any company	Attri et. al (2013)
Organizational structure (F12)	Organization structure means an overall network and layout. Indian railways have well defined organizational structure with relevant departments for coordination and supervision.	Sayali et. al (2014)
Station layout (F13)	The layout of the Railway station is very crucial as it helps in better service to passengers. It is very important in areas where space is scarce.	Ping Lu et al. (2017)
Network topology (F14)	The topology of network is a dire factor as connectivity planning is necessary. For example if one line needs repairs It should not stop functioning of other lines or create train delays.	Szkoda et al. (2016), Ghosh et. al (2013)
Emergency management plan (F15)	The emergency management plan is necessary for disaster situations to prevent losses both economic and social.	Isha et al. (2015), Burton et al. (2001)

III. RESEARCH METHODOLOGY

The Research methodology divided into four steps had better understand the relationship between the vulnerable factors found using extensive literature review. After that factor were analyzed, an integrated approach of Decision-Making Trail Evolution Laboratory (DEMATEL) and total interpretative structural modeling (TISM) is used. DEMATEL used to set a priority order for vulnerable factors in Indian railways and weights assigned to each one of them so that a complex and impact relationship can be drawn among factors. TISM model used to find correlation between different subset of factors so that a model based on dependencies formed for better layout and priority management of northern Indian railways network. In spite the fact that both techniques are decade old but they stand on the merit of flexibility and robustness. Furthermore, they had not utilized in Indian railway network before for robust and sturdy model of organizational layout.

A. Identification and categorization of vulnerable factors through an extensive review of literature

Based on the study of different research papers of Indian railways 15 vulnerable factors are identified and further categorized into six categories so that the integrated model of DEMATEL and TISM can be applied.

B. Factors are prioritized and correlations are drawn using TISM model

The TISM methodology stands for Total Interpretive Structural Modelling (TISM).

TISM is pair examination strategies to advance various leveled connections among a lot of components. This technique helps to change over poorly organized mental models into well-explained models that go about as base for conceptualization and hypothesis building. Over the ongoing decade, numerous examinations have been done on the use of TISM and wide ranges of variations have been advanced in the writing. The total interpretive structural modeling (TISM) technique is an extension of interpretive structural modeling (ISM). The TISM strategy is utilized to build up the various leveled relationship among the factors of interest. The focal instrument of ISM, for example reachability matrix and its partitions are embraced, as it is a part of TISM technique. The TISM technique is a nine-step procedure, this figure 1 explains about the steps followed in series in this research methodology. The steps have been discussed later the flow chart. Various steps have been followed to apply this research methodology.

The very first step is to find out the parameters to be linked. Then a suitable relationship is identified around the parameters based on expert opinion. The next step is to develop the questionnaire done with the help of google form for collecting the data based on expert opinion. Later the questionnaire is sent to various experts of the industries send through messenger, mails and personally visiting the experts to complete this step of the process. The fourth step is the analysis of the data, which is reliability analysis of factor analysis (relationships among parameters). The software used to complete the process is Microsoft Excel. After the parameter analysis, next step is to implement the TISM approach is gradually applied in order to conclude the result. A digraph is used for finding the result and conclusion.

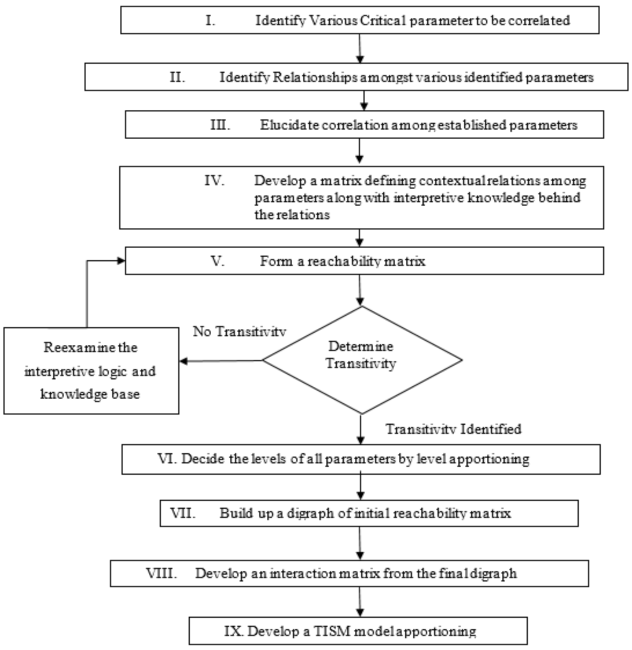

Fig. 1. Flow for TISM modeling

- Step 1: Identify the parameters

The parameters in the study for the modeling which critical for northern railways network are identified through literature and expert opinions.

- Step 2: Define a dependent relationship

To build up the structure, it is basic to characterize the logical connection between the factors/variables of interest. Here, the relevant relationship distinguished between the vital variables is "Factor A will impact or improve Factor B". A model might be "Government approaches will impact or upgrade furious challenge".

- Step 3: Understanding of the relationship

This progression gives TISM an edge over conventional ISM, as the previous looks for an understanding of the connections. Concerning this research, the understanding will be "How to factor A will impact or improve factor B?" It will help accomplish inside and out learning express.

- Step 4: Interpret the logic of pair-wise examination

An "Interpretive Logic-Knowledge Base" can be made for pair-wise examination of the parameters; the response for every correlation might be Yes (Y) or No (N). In the event that the appropriate response is Y, further interpretation is fundamental done by the experts to understand the reason for the relationship between two parameters. The views of the experts are used to develop an interpretive logic knowledge base.

Table- II: Structural self-interaction matrix (SSIM)Error! Not a valid link.Table- III: Rule for transforming SSIM to Reachability matrix

(i-j) Entry	(i to j) Relation	(i to j) Relation
X	1	1
O	O	O
V	1	O
A	O	1

- Step 5: Forming of reachability and transitivity check

The interpretations of the identified relationship set up in Step III have been utilized as a premise to the reachability matrix. It is acquired by entering 1 or 0 in the I-j cell of the network (where I is line and j is section) instead of 'Y' or 'N', individually. At that point, the network is tried for transitivity. Transitivity exists if a backhanded relationship exists among variables that mean if factor A prompts factor B and factor B prompts factor C, at that point factor A will likewise prompt factor C. By embedding transitivity in the reachability matrix, the last reachability matrix has been acquired.

Transitivity adding in the initial reachability matrix is an iterative process. For every transitivity link, the initial reachability matrix is updated and ‘N’ entry is altered to ‘Y’ entry. Finally, ‘transitive’ has been written in the interpretation column.

Table- IV: Final Reachability Matrix for Critical Success Factors

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	**Driving Power**
F1	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	**3**
F2	1	1	1	1	1	1	1	0	1	1	0	0	0	0	0	**9**
F3	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	**4**
F4	0	0	0	1	1	0	0	1	0	0	1	0	0	0	0	**4**
F5	0	0	0	1	1	0	0	1	0	0	1	0	0	0	0	**4**
F6	0	1	0	0	1	1	0	1	0	1	0	0	0	0	0	**5**
F7	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	**4**
F8	0	0	0	1	1	0	0	1	0	0	1	0	1	0	0	**5**
F9	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	**2**
F10	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	**3**
F11	0	0	0	1	1	0	0	1	0	0	1	0	0	0	0	**4**
F12	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	**3**
F13	0	0	1	0	0	0	1	0	1	0	0	0	1	0	1	**5**
F14	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	**3**
F15	1	0	1	0	0	0	1	0	1	0	0	0	1	0	1	**6**
	5	**3**	**5**	**5**	**6**	**3**	**5**	**5**	**4**	**3**	**4**	**4**	**5**	**3**	**4**	

- Step 6: Level partitioning of the reachability matrix

The reachability set and the antecedent set have been identified for each parameter from the initial reachability matrix. When both the intersection set and the antecedent set are similar, a level has been assigned to each parameter. Once the level is allocated to a factor, it is not considered in the next iteration. This procedure is repeated until levels of all the parameters are identified as shown in Table 5 and Table 6.

Table- V: Iteration 1

CSF	Reachability Set	Antecedent Set	Intersection	Level
1	**1,12,14**	**1,2,12,14,15**	**1,12,14**	**I**
2	1,2,3,4,5,6,7,9	2,6	2,6	
3	3,7	2,3,7	3,7	
4	4,5	2,5,6	5	
5	4,5,8	2,4,5,6,8	4,5,8	
6	2,5,6,8,10	2,6,10	2,6,10	
7	3,7,13	2,3,7,13	3,7,13	
8	5,8,11,13	5,6,8,11	5,8,11	
9	9,12	2,9,13,15	9	
10	6,10	6,10	6,10	
11	8,11	8,11	8,11	
12	**1,12,14**	**1,9,12,14**	**1,12,14**	**I**
13	7,9,13,15	7,8,13,15	7,13,15	
14	**1,12,14**	**1,12,14**	**1,12,14**	**I**
15	1,9,13,15	13,15	13,15	

Table- VI: Iteration 2-7

CSF	Reachability Set	Antecedent Set	Intersection	Level
2	2,3,4,5,6,7,9	2,6	2,6,10	V
3	3,7,13,15	2,3,7,13,15	3,7,13,15	III
4	4,5,8,11	2,4,5,8,11	4,5,8,11	IV
5	4,5,8,11	2,4,5,6,8,11	4,5,8,11	IV
6	2,5,6,8,10	2,6,10	2,6,10	V
7	3,7,13,15	2,3,7,13,15	3,7,13,15	III
8	4,5,8,11,13	4,5,6,8,11	4,5,8,11	IV
9	9	2,9,13,15	9	II
10	2,6,10	2,6,10	2,6,10	V
11	4,5,8,11	4,5,8,11	4,5,8,11	IV
13	3,7,9,13,15	3,7,8,13,15	3,7,13,15	III
15	1,3,7,9,13,15	3,7,13,15	13,15	III

Table- VII: Variable and Respective level

S. No.	Factors	Code	Level in TISM
1	Individual technical capability	F1	I
2	Organizational structure	F12	I
3	Network topology	F14	I
4	Safety investment	F9	II
5	Equipment/facility condition	F3	III
6	Social environment	F7	III
7	Station layout	F13	III
8	Emergency management plan	F15	III
9	Equipment/facility performance	F4	IV
10	Equipment/facility protection	F5	IV
11	Operating environment	F8	IV
12	Rules and regulations	F11	IV
13	Individual workload and stress	F2	V
14	Natural environment	F6	V
15	Education and training	F10	V

- Step 7: Digraph formation

A digraph formed consists of nodes and arrows. Each node represents parameters and each arrow represents direction of relationships between two parameters. Every parameter is arranged in the digraph as per the level obtained during level partitioning. The directions of relationships established as per the reachability matrix. Indirect relationships are thus shown in the final digraph with the dotted line.

- Step 8: Interaction matrix

A binary matrix formed by translating the final digraph. In this matrix, '1' used to indicate direct and significant transitive links. Further developed as an interpretive matrix by providing the relevant interpretation from the knowledge base

Table- VIII: Represents the transitivity links between the factors

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15
F1	-	0	0	0	0	0	0	0	0	0	0	1	0	1	0
F2	1	-	1	1	1	1	1	1*	1	1*	1*	1*	1*	1*	1*
F3	1*	0	-	0	0	0	1	0	1*	0	0	1*	1*	1*	1*
F4	1*	0	1*	-	1	0	1*	1*	1*	0	1*	1*	1*	1*	1*
F5	1*	0	1*	1	-	0	1*	1	1*	0	1*	1*	1*	1*	1*
F6	1*	1	1*	1*	1	-	1*	1	1*	1	1*	1*	1*	1*	1*
F7	1*	0	1	0	0	0	-	0	1*	0	0	1*	1	1*	1*
F8	1*	0	1*	1*	1	0	1*	-	1*	0	1	1*	1	1*	1*
F9	1*	0	0	0	0	0	0	0	-	0	0	1	0	1*	0
F10	1*	1*	1*	1*	1*	1	1*	1*	1*	-	1*	1*	1*	1*	1*
F11	1*	0	1*	1*	1*	0	1*	1	1*	0	-	1*	1*	1*	1*
F12	1	0	0	0	0	0	0	0	0	0	0	-	0	1*	0
F13	1*	0	1*	0	0	0	1	0	1	0	0	1*	-	1*	1
F14	1	0	0	0	0	0	0	0	0	0	0	1*	0	-	0
F15	1	0	1*	0	0	0	1*	0	1	0	0	1*	1	1*	-

- Step 9: Forming a TISM model

In the final step, a TISM based framework has been developed using a digraph and interpretive matrix. In this framework, the interpretation of each relationship of parameter is mentioned. This framework clearly displays the driving power as well as the dependence power of each parameter affecting the working of northern Indian railways the most.

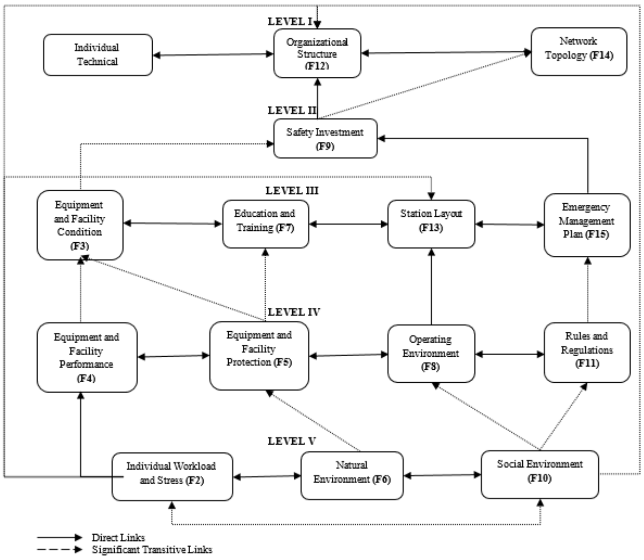

Fig. 2. Digraph representation of links and nodes

C. DEMATEL approach for finding the priority of grouped factors categorized using TISM model above

The DEMATEL methodology is Decision making trial and evaluation laboratory (DEMATEL) considered an efficient method for the identification of cause-effect chain components of a complex system. It deals with finding interdependent relationships among factors and finding the critical ones through a visual structural model. Over the recent decade, many studies done on the application of DEMATEL and many different variants had forward in the literature.

Figure 3 explains about series of steps followed in research methodology. These steps discussed below after the flow chart. Different steps followed in flowchart of research methodology. The first step is to identify the challenges, which are collected on the basis of expert opinion.The expert opinion is taken by sending questioner and the second step is questioner development, which is done by Google form. After this questioner is sent to different experts in the railway industry working in different industry which is send through mail, messenger and by visiting industries and diesel sheds. The fourth step is collection of data and analysis which is also of two types one reliability analysis and other is factor analysis. This was done using software's and they are as follows –SPSS-23 and Microsoft Excel. After factor analysis and reliability analysis, the next step is implementation of DEMATEL approach in which systematic approach applied so that we can come with results and conclusions. The casual diagram helps in finding out the result and conclusion.

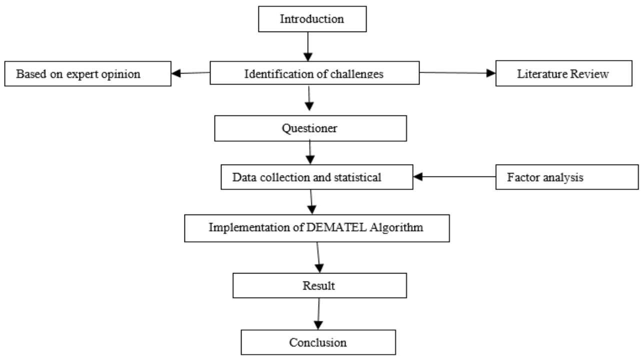

Fig. 3. Flow chart of Research Methodology

Expert opinions collected through e-mail, questionnaires, and face-to-face interaction. The entire research intention is to find out the main SCM challenges of dairy industry. Identified challenges may be represented as- M1- Government Policies, M2 – Individual Performance, M3 – Management of overall network and coordination among employees, M4 – Environment Conditions of diesel sheds, M5 – Emergency Measures during disaster situation, M6 – Network and layout of northern railways, and M7 – Condition of Equipment and Facilities at railway diesel shed.

The DEMATEL approach deals with both direct as well as indirect influences of one criterion over another criterion and filters the efficacious criteria. The existing steps of DEMATEL method are given as-

- Step 1: Calculate the average direct relation matrix:-

In this step, the data collected in the form of the opinion of expert that was regarding the impact of i^{th} criteria over the j^{th} criteria. For i = j, the diagonal elements are set to zero. For each respondent, a non-negative matrix given as:

$$Y^r = [y_{ij}^r]_{n\times n}, \qquad (1)$$

Where 'r' is the number of respondent's i.e. $(1 \le r \le m)$ and x_{ij} represents the degree of respondents' believes of i^{th} criteria over the j^{th} criteria. Then summarize the opinions of 'm' respondents and find out the average direct relation matrix as given in equation 1.

$$B = [b_{ij}] \qquad (2)$$

Where $b_{ij} = \frac{1}{m}\sum_{r=1}^{m} y_{ij}^r$

Table- IX: Average direct relation matrix

	M1	M2	M3	M3	M5	M6	M7	SUM
M1	12	3.625	3.125	3.125	3.2857	3.875	3.25	20.852
M2	3	0	3.25	3.25	3.375	3.375	3.5	19.75
M3	2.5	3	0	3.75	3.5	3.75	3.5	20
M4	3.37	3	3.75	0	3.5	3.5	3.625	20.75
M5	3.75	3.625	3.875	3.625	0	3.5	3.125	**21.5**
M6	4.22	4	3.125	2.875	3.25	0	3.625	21.097
M7	3.71	3.375	3.625	3.625	3.625	3.5	0	21.464
SUM	20.56	20.625	20.75	20.25	20.535	**21.5**	20.625	

- Step 2: Determine normalized direct-relation matrix 'N'

$$N = C \times B \qquad (3)$$

Where $C = \frac{1}{\max_{1\le i\le n} \sum_{j=1}^{n} b_{ij}}, \quad i,j = 1,2,\ldots\ldots,n$

Table- X: Normalized direct relation matrix

	M1	M2	M3	M3	M5	M6	M7
M1	0	0.16	0.14	0.14	0.15	0.18	0.15
M2	0.13	0	0.17	0.15	0.17	0.17	0.16
M3	0.11	0.13	0	0.17	0.16	0.17	0.16
M4	0.15	0.13	0.17	0	0.16	0.16	0.16
M5	0.17	0.16	0.18	0.16	0	0.16	0.14
M6	0.19	0.18	0.14	0.13	0.15	0	0.16
M7	0.17	0.15	0.16	0.16	0.16	0.16	0

- Step 3: Estimate the total relation matrix 'T' using equation 3:-

$$T = N(I - N)^{-1} \qquad (3)$$

Where '*I*' is the Identity matrix.

Table- XI: N (N-I) INVERSE (TOTAL RELATION MATRIX)

	M1	M2	M3	M3	M5	M6	M7
M1	-0.09173	0.110572	0.076572	0.08265	0.088377	0.122086	0.087152
M2	0.067287	-0.0945	0.112695	0.084971	0.114925	0.110316	0.099948
M3	0.03833	0.073157	-0.09317	0.123236	0.103886	0.117018	0.104563
M4	0.093435	0.068922	0.114587	-0.09197	0.099935	0.094725	0.109641
M5	0.116113	0.106147	0.118682	0.107495	-0.09874	0.089374	0.072331
M6	0.147352	0.130892	0.072338	0.061677	0.081235	-0.10289	0.108414
M7	0.112218	0.089484	0.102305	0.107565	0.104372	0.090278	-0.09668

- Step 4: Development of causal diagram

The sum of rows (H) and the sum of columns (V) of the total correlation matrix 'T' are calculated. Then, 'Prominence' (H + V) and 'Relation' (H - V) have been calculated, to provides the relative importance and categorization in to cause and effect group of each criterion. It is predicated on positive and negative criterion, If 'Relation' is positive, then criterion will subsist in cause group while with negative 'Relation', falls under effect group. By mapping the dataset of (H + V, H - V), casual diagram is obtained, to observed some visions for decision making

$$T = [t_{ij}]_{n\times n}, \quad i,j = 1,2\ldots.,n \qquad (4)$$

$$H = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} = [t_i]_{n\times 1} \qquad (5)$$

$$V = \left[\sum_{i=1}^{n} t_{ij}\right]_{1\times n} = [t_j]_{1\times n} \qquad (6)$$

Table- XII: The sum of influences given and received on criteria

	H	R	H + R	H - R
M1	0.475679	0.483006	0.958685	-0.00733
M2	0.495646	0.484677	0.980323	0.010969
M3	0.467018	0.504005	0.971023	-0.03699
M4	0.489271	0.475621	0.964892	0.013651
M5	0.511401	0.49399	1.00539	0.017411
M6	0.499022	0.520911	1.019933	-0.02189
M7	0.50954	0.485367	0.994907	0.024173

IV. RESULT AND DISCUSSION

TISM model was obtained in Figure 2 and further priority mapping of grouped vulnerable factors was obtained through the DEMANTEL approach. In order to further classify the critical parameters affecting Indian railways network, the driving and dependence correlation of these factors was obtained from final reachability matrix. The driving and dependence of these factors were then plotted graphically for MIC-MAC analysis. The ordinate represents driving power whereas the abscissa represents the dependence power.

The graph is further divided into four quadrants. Quadrant 1 represents autonomous variable, Quadrant 2 shows the dependent variables, Quadrant 3 represents linkage variables and Quadrant 4 shows independent variables, which are also called driver variables. Any factor, which is present in quadrant, I is considered as more or less independent in nature. It is not linked with other parameters for change. Parameters in quadrant II are mostly dependent on other factors but they do not influence other parameters. They are known as dependent factors. The quadrant III parameters are connecting factors as they act as link among other parameters and are termed as linkage factors. Finally, the parameters of IV clusters have highest driving power, they influence other factors mostly, and by themselves, they are independent in nature. Thus, special attention is required for these parameters, as they are known as game-changer variables.

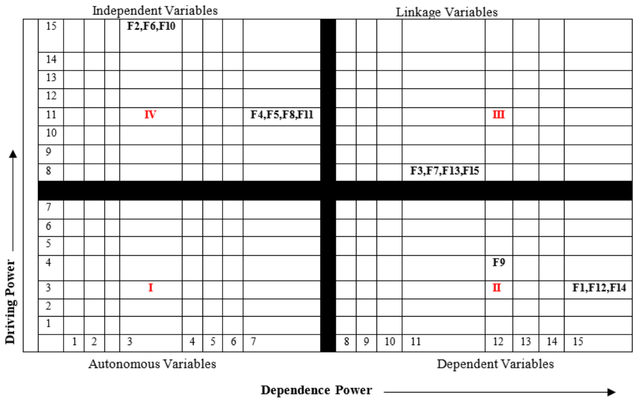

Fig. 4. Driving power and Dependence Power Diagram

The Total interpretative structural modeling based conceptual framework was developed and shown in Figure 2. The derived model is obtained from critical parameter determined from vast review of the literature and expert-based opinions of northern railway network. The theoretical model present gives idea for management of Indian railways network for better performance and greater reliability. The direction of correlations established among factors gave a wide view of dependence and as well as independence relations of various factors so that immediate attention can be drawn in case of failure in railway network.

Individual workload and stress, Natural environment, Education and training emerged as the key parameters essential for developing the strong and reliable network for Indian railways as they come under the fourth quadrant meaning independent variable. These factors are responsible for driving others to change while they remain independent change from others. So Indian railway network should focus on training and education of employees for better performance and reliability in diesel locomotive sheds. In addition, there is need to focus Individual workload and stress as it can create problems due high pressure and fatigue. Each individual should be given prescribed work hours and achievable goals throughout the working period for better results. Locations of railways networks and diesel sheds are also important as certain locations in India are disaster-prone and can cause delay/ damage due to natural environment. So robust and fail-proof planning is required to ensure smooth working of network and better service. Also, there is transitive link between individual stress and education training as they are correlated to performance factors that analyzed using DEMANTEL approach. Furthermore above factors are correlated to each other on some level meaning improvement in one parameter can greatly benefit other factors as well.

Equipment and Facility performance can be enhanced if individual workload and stress are reduced which can further benefit protection of Equipment and facilities. It is clear indicator in TISM model that operating environment, rules, and regulations are correlated to each means they can be influenced and optimized mutually which can further enhance the whole chain of facility protection and performance that is further connected to level V parameters of model that are discussed above. In addition, it can be seen from model that there are many direct links among parameters that can be used to improve the functioning of Indian railway network. Level I factors like Individual technical capability, network structure, and network topology are directly correlated to each other as better organizational structure can only be achieved through capable employees and better network layout of railways also safety investment that are mostly carried through government policies is directly related to organizational structure that can influence the whole network. Other parameters that directly correlated in model are emergency management plans, station layout, social environment, Equipment, and facility condition. Correlation among which are clearly indicated in the TISM model diagram above.

Transitive links among factors mean though they are not directly related but are changed mutually in simple mathematical terms means if X is factor of Y and Y is factor Z, then there is transitive link if X is a factor of Z as well. Thus in TISM model transitive links are shown and it is clearly understood that safety investment can cause change in network topology indirectly as safer network is much more reliable. In addition, education, training, individual workload and stress are indirectly influencing the organizational structure of Indian railways network. Other prominent transitive links are correlation among Equipment and facility performance, protection, and condition as they are all subgroups of Equipment and Facility as whole parameter. Rules and regulations form significant transitive link between management plans at the time of emergency.

The MIC-MAC analyses done above are formed by the property of multiplications in matrices. The main motive of this analysis classifies the factors above shown in figure 4. It is clear that there are no autonomous factors that are cluster I, which means that all factors in system are interconnection with each other. Parameters such as Individual technical capability, Organizational structure, and Network topology falls under cluster II and are called dependent factors. These are primarily responsible for dependence rather than driving. These occupy top-level in TISM model and are highly influenced factors like Equipment and facility performance, individual workload, and stress, social environment, etc. cluster III refers to the connecting factors that act as correlating link between the driving and dependent factors of the model.

Equipment/facility condition, Social environment, Station layout, and Emergency management plans are dependent on the elements of cluster IV, such as Equipment/facility performance and protection, Operating environment, Rules and regulations, Individual workload and stress, Natural environment, Education and training. They are also liable for driving factors of cluster II.

To further improve the study model DEMATEL approach was applied to prioritize the grouped parameters. Since applying the approach to 15 critical factors is very tedious task and not much information of priority can be drawn from casual diagram. Therefore, determined critical factors were grouped to form 6 main categorical variables and DEMATEL approach was applied. The identified challenges were :- M1- Government Policies, M2 – Individual Performance, M3 – Management of overall network and coordination among employees, M4 – Environment Conditions of diesel sheds, M5 – Emergency Measures during disaster situation, M6 – Network and layout of northern railways, and M7 – Condition of Equipments and Facilities at railway diesel shed. The casual diagram is drawn below.

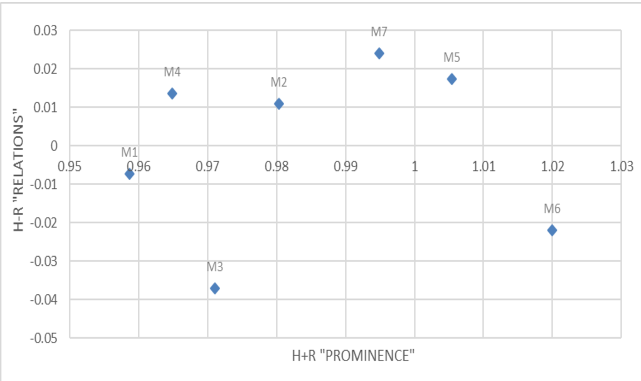

Fig. 5. Casual Diagram for priorities

M6 - Network and layout of northern railways comes out with highest importance rating of 1.0199 and with lowest importance rating of 0.9586 is M1 – Government policies. M1- Government Policies, M3 – Management of overall network and coordination among employees and M6 – Network and layout of northern railways exist in effect group due to negative (H-R) value while M2 – Individual Performance, M4 – Environment Conditions of diesel sheds, M5 – Emergency Measures during disaster situation and M7 – Condition of Equipments and Facilities at railway diesel shed comes in cause group category with positive (H-R) value and have significant impact on effect group practices. Finally the importance order can be seen as M6>M5> M7>M2> M3>M4>M1.

V. CONCLUSION

The research study attempted a TISM – DEMATEL integrated approach to provide insights to both academics and practitioners working in Indian railways network as safety and reliability is considered most crucial consideration of railway network. Thus understanding the main influencing parameters in Indian railways through literature and expert opinions was the key role of this study. Based on vulnerable factors obtained TISM model was prepared and key driving and dependence factors was jotted down using MIC MAC analysis. TISM technique used was very helpful in determining the conceptual framework for indian railway network after that key factors were further grouped in 6 categorical variables which was further optimized for getting and cause and effect groups among parameters. As the DEMATEL, approach gave priority order for cluster of variable this research study can be used to create better model with priority factors for better organization management in Indian railways network for much reliable and efficient system. The crucial weighted parameters were quantified and interrelation among them are used to propose a integrated method.

Thus it can be suggested the network layout of railways are most crucial when comes to cost cutting and profits of railway network and main independent factors which most crucial including priorities weights are emergency management plans, Equipment and Facility conditions and network layout of Indian railway network.

However, the assessment of these critical parameters are based on subjective result of expert opinion and literature thus it requires rigorous validation for acceptance throughout the network of Indian railways. Beside these limitations of study the presented the prioritized framework which was developed for foundation managerial effort for reliable and better system of railway network.

VI. SCOPE FOR FUTURE RESEARCH

This research effort provide an opportunity for future research in Indian railway sector that is considered biggest railway network in world. The current study is limited to only 15 vulnerable parameter for building the conceptual framework that can serve as foundation for future models as more and more parameters can be correlated together for much reliable and robust system. Also, the group factors can be analyzed using different operation research model for better optimization of factors and greater priority graphs can be drawn.

In addition, the model can be formed and applied to a more functional level so that it can help the organizational structure of Indian railways. For future in this study, a comparative analysis of importance ratings obtained from DEMATEL approach and can be done by Preference rating approach. This preference rating approach has been integrated in two phases as stage 1, CPR way to deal with deciding the RIR of issues was utilized. For this execution, PG depends on field master's assessments utilizing chart hypothesis based portrayal system was produced. Further, in arrange 2: CSA approach was utilized to assess the competitive priority rating of each issue as for each thought to be focused methodology. This approach can be utilized as a part of future with DEMATEL keeping in mind the end goal to enhance exactness.

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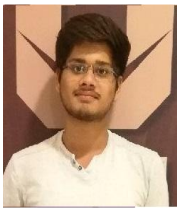

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