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TISM Based Hierarchical Analysis of Factors Leading to Accidents on Indian Highways

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Abstract

Road accidents are one of the major cause of death worldwide. As per Global safety report, more than one million people are killed in road accidents every year throughout the world. The probability of occurrence of accident depends on numerous factors like roadway condition, geometrics of roads, type of vehicle, pavement condition and weather condition etc. Each factor contributes its own share towards occurrence of accident & there can be many more factors which are situation specific to ascertain the effect of various parameters on accident occurrence, data of road accident for a substantial stretch of an Indian national highway was collected for past three years. Also, the present study implements Total Interpretive Structural Modeling (TISM) to establish relationship between identified variables in a flowchart format to understand the situation of affecting variables in a systematic manner. It is observed that there are four levels in the diagraph and road feature is observed to be the most important variable on which all the other variables depend. Classification is tertiary in the hierarchy whereas road condition and weather condition are observed to be variables with most number of connections and high level of interdependence.

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Keywords: Accident; road condition; highways; road safety; causes

1. Introduction

In today's era of global development, road and transport has become a vital part of growth and development of a nation. Journey from developing to developed nation has increased the quantum of infrastructural development across India. The present road network has helped in reducing the distance and reducing the travel time. This has not only increased the number of accidents but also life risk. As per the records of government agencies, road accidents result in loss of lakhs of lives and serious injuries to crores of people every year. India has a total of about 2 million kilometers of road network. Out of the total spread, approximately 960,000 km are surfaced roads and about 1 million km of road

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length are of poor quality. Rural areas have unsurfaced roads & urban areas have high severity of congestion. These are some of the major problems faced on any Indian roads. This is very serious situation and requires proper attention with the use of some statistical methods.

The number of road commuters is increasing drastically demanding safer roads. A lot of initiatives are being taken up by the government to tackle this issue. A total of 7 factors affecting road accidents are observed and data pertaining to the same is collected for a stretch of 101 kilometers of a National Highway in India. This study implements TISM technique to establish the relationship between these factors to understand the parameters of road safety better.

1.1 TISM technique and its use

Interpretive Structural Modelling (ISM) is an entrenched methodology which is used for recognizing and categorizing relationships among variables that delineate an issue. The approach has been progressively exercised by many researchers for varied applications dating back to 1970s (Sandbhor et al, 2015) ISM has been used to identify the key factors of energy conservation in Indian cement industry (Saxena, et al, 1992). It has been implemented to analyse attributes contributing to vendor selection (Mandal and Deshmukh,1994), construction company growth enablers (Bhattacharya and Momaya, 2009), flexible manufacturing systems (Raj et al, 2008), success factors affecting implementation of advanced manufacturing technologies (Singh et al 2007), quality management (Sahney et al, 2010), supply chain management (Qureshi et al, 2008; Singh, 2011), assessing customer involvement in greening of the supply chain (Kumar, et al 2013), six sigma (Soti et al, 2010), airline performance assessment through total quality management (Singh and Sushil, 2012). By interpreting the nodes as well as links in the model, an ISM can be upgraded to Total Interpretive Structural Model (TISM) (Attri et al, 2013; Sandbhor et al, 2015).

TISM is an advanced edition of ISM technique (Warfield, 1974) that is used to model the factors for better comprehension of their interaction (Sushil (a), 2005; Sushil (b), 2005; Bhattacharya and Momaya, 2009; Sushil, 2012). TISM has found its application in various recent researches. It has been used for modeling the parameters affecting e-government by Naseem (2011). Prasad and Suri (2011) implemented TISM to assess relationship between variables affecting private higher technical education. Srivastava and Sushil (2013) tested the applicability of TISM for strategic performance factors for effective strategy execution. In a study by Sandbhor and Botre (2014), factors affecting labour productivity have been arranged hierarchically to improve performance of construction site and in another study by Sandbhor et al (2015), factors affecting construction project success are assessed using TISM. Following sections describe in detail the implementation of TISM to selected area of application.

2. Data Collection

Road accidents are one of the major reasons of casualty in India. Statistics insinuate that one life is lost every four minutes on Indian roads (http://timesofindia.indiatimes.com/topic/Road-accident). In spite of this, not much effort is made to make roads safer. National highway (NH9) is a major East – West highway in India that passes through almost 7 states. In present case study, data pertaining to accidents on a 101 kms stretch on this highway from Pune city to Solapur city in Maharashtra state of India is collected. Data for 3 years is taken into consideration for analysis. The data includes information of the accidents that have taken place at various locations during three years' span. The information is collected in terms of identified variables. Total 7 parameters have been identified which are further subdivided into various categories as shown in Table 1 (Badgujar et al, 2017).

A survey instrument has been designed by incorporating the 7 variables causing accidents. In the survey, the proposed variables are rated by identified experts, selected using judgemental sampling. The questionnaire asks to correlate the variables and their interdependence in required format. The questionnaire has been distributed either personally or via e-mail to members with experience of 10- 35 years in various infrastructure companies. The sample size collected is 25.

Table 1: Details of variables/ parameters considered for the study

Parameters	Categories
Nature of Accident	Overturning Head on Collision Rear End Collision Collision Brush Right Turn on Collision Skidding Other
Classification of accident	Fatal Grievous Minor Injury Non-Injury
Causes of accidents	Drunken Over Speeding Vehicle Out of Control Fault of Driver Defect in Vehicle
Road Feature	Single Lane Two Lane Three Lane or More Without Central Divider Four Lane or More With Central Divider
Road Conditions	Straight Road Slight Curve Sharpe Curve Flat Road Gentle Slope Steep Slope Hump Dip
Intersection Type and Control	T Junction Y Junction Four Arm Junction Staggered Junction Junction with More Than Four Arms Roundabout Junction Manned Rail crossing Unmanned Rail Crossing
Weather Conditions	Fine Mist /Fog Cloud Light Rain Hail Snow Strong Wind Dust Storm Very Hot Very Cold Other Extraordinary Weather Conditions

3. Application of TISM

Process of TISM starts with identification of variables as described in detail in the previous section. This is followed by preparing a Structural Self-Interaction Matrix (SSIM) and Reachability Matrix (RM), as discussed in subsequent sections.

3.1 Organizing Structural Self Interaction Matrix (SSIM)

Firstly, the seven identified variables are placed in a matrix form with rows and columns representing variable titles. SSIM represents the relation between row factor i and column factor j in terms of V, A, O and X. To corroborate the existence of a relation between any two variables and the linked direction of relation, expert advice is requested. The responses are collected from road safety auditors using a systematic instrument. Four symbols V, A, O and X are used to symbolize the nature of relation between pair of variables (Sandbhor et al, 2015). The symbol V is assigned when i leads to j but j does not lead to i. Symbol A is assigned j leads to i but i does not lead to j. Symbol X is assigned when i leads to j and j leads to i and O stands for no valid correlation.

SSIM for the variables under consideration is then prepared (Table 2) by entering the responses of the experts on pair-wise interaction between the variables (Sandbhor et al, 2015; Bhattacharya and Momaya, 2009). The significance of SSIM can be understood by understanding the matrix shown in Table 2. For example, nature of accident (F1) does not lead to weather condition (i does not lead to j) but weather condition (F7) leads to nature of accident (j leads to i). This relation is exhibited in the matrix by allotting A in the relevant box. Likewise, all the other relations are displayed.

Table 2: Structural Self Interaction matrix

	Variable	F7	F6	F5	F4	F3	F2	F1
F1	Nature of accident	A	A	A	A	X	V	-
F2	Classification accident	A	O	A	A	A	-	
F3	Cause of accident	A	O	A	O	-		
F4	Road feature	O	V	O	-			
F5	Road condition	O	O	-				
F6	Intersection	O	-					
F7	Weather condition	-						

3.2 Reachability Matrix (RM)

RM is arranged on the basis of SSIM. Information in each item of the SSIM is transferred into binary format. Table 3 gives the basis for binary conversion. The i to j relations and corresponding values help in preparing RM. For example, F1 and F7 have "A" relation in SSIM, that assigns a "0" for F1 to F7 (i to j) in the first row and assigns a "1" for F7 to F1 (j to i) in the last row. Entry for a variable with itself is denoted by 1 in RM (Table 4).

Table 3: Rule for transforming SSIM to RM

(i-j) Entry	(i-j) Relation	(j-i) Relation
V	1	0
A	0	1
X	1	1
O	0	0

Table 4: Reachability Matrix

Variable Code	F1	F2	F3	F4	F5	F6	F7
F1	1	1	1	0	0	0	0
F2	0	1	0	0	0	0	0
F3	1	1	1	0	0	0	0
F4	1	1	0	1	0	1	0
F5	1	1	1	0	1	0	0
F6	1	0	0	0	0	1	0
F7	1	1	1	0	0	0	1

3.3 Levels of Reachability Matrix

The level partitioning is effected to know the hierarchy of variables that involves preparing Reachability Set (RS) and Antecedent Set (AS). RS for a variable represents variable number that carries value 1 in row of that variable. Variables carrying value 1 in column of that variable are placed under AS. If intersection of the RS and AS is same as RS for a particular variable, it is allotted a level. Elements/ variables satisfying the above condition are eliminated from the element set in order to continue iterations for remaining elements. Iterations are conducted till the levels of all variables are determined (Attri et al, 2013; Bhattacharya and Momaya, 2009).

Table 5 below shows the iterations and Table 6 summarizes the results of iterations and represent the levels of all the variables.

Table 5: Level partitioning of variables

Variable	Reachability Set (RS)	Antecedent Set (AS)	RS ∩AS	LEVEL
		Iteration 1		
F1	1,2,3	1,3,4,5,6,7	1,3	
F2	2	1,2,3,4,5,7	2	I
F3	1,2,3	1,3,5,7	1,3	
F4	1,2,4,6	4	4	
F5	1,2,3,5	5	5	
F6	1,6	4,6	6	
F7	1,2,3,7	7	7	
		Iteration 2		
F1	1,3	1,3,4,5,6,7	1,3	II
F3	1,3	1,3,5,7	1,3	II
F4	1,4,6	4	4	
F5	1,3,5	5	5	
F6	1,6	4,6	6	
F7	1,3,7	7	7	
		Iteration 3		
F4	4,6	4	4	
F5	5	5	5	III
F6	6	4,6	6	III
F7	7	7	7	III
		Iteration 4		
F4	4	4	4	IV

Table 6: Variable levels

Factor	Code	Level in TISM
Classification of accident	F2	I
Nature of accident	F1	II
Cause of accident	F3	II
Road condition	F5	III
Intersection	F6	III
Weather condition	F7	III
Road feature	F4	IV

3.4 Diagraph Model

The variables are arranged in a flowchart format in accordance with their levels. The direct and indirect or significant links are shown as per the relationships observed in the reachability matrix. The diagrammatic representation of the direct and indirect links also known as diagraph is shown in Fig 1.

4. Observations

Interaction matrix represents the direct and significant links of variables at a glance. Table 7 gives interaction matrix with direct link represented by “a” and significant link by “b”. Figure 2 represents the driving and dependence power relationship of variables as attained from the diagraph model. Quadrant I signifies autonomous variables with less driving and dependence power. Quadrant II clusters dependent variables with high dependence power. Quadrant

III signifies linkage variables that possess high driving as well as high dependence power whereas quadrant IV clusters independent driver variables.

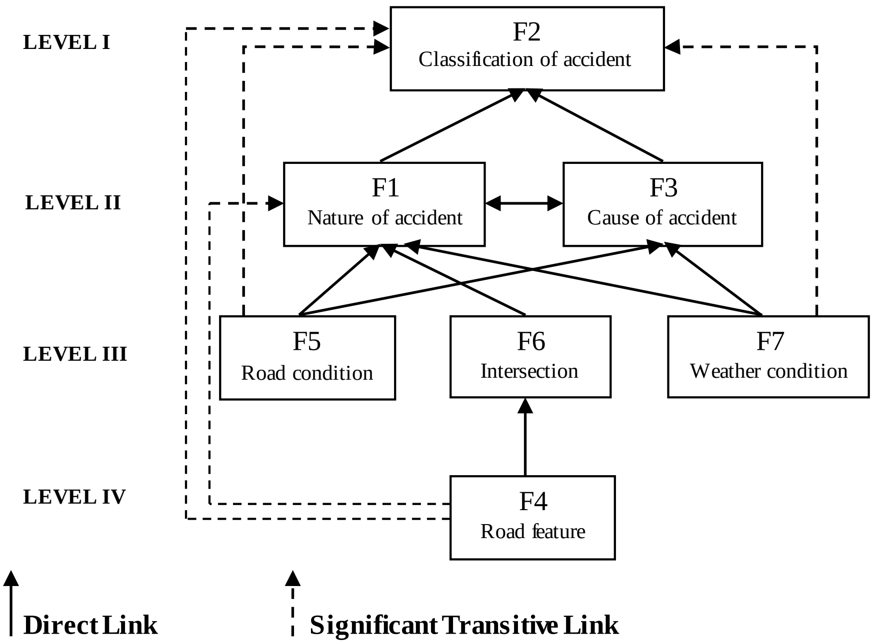

Fig. 1. Diagraph Model Leading to Direct and Indirect Link

Table 7: Interaction matrix

Factor	F1	F2	F3	F4	F5	F6	F7
F1	-	1(a)	1(a)	0	0	0	0
F2	0	-	0	0	0	0	0
F3	1(a)	1(a)	-	0	0	0	0
F4	1(b)	1(b)	0	-	0	1(a)	0
F5	1(a)	1(b)	1(a)	0	-	0	0
F6	1(a)	0	0	0	0	-	0
F7	1(a)	1(b)	1(a)	0	0	0	-

Nature of accident (F1), Classification of accident (F2) and Cause of accident (F3) fall in IInd quadrant having strong dependence and weak driving power. Road feature (F4) lies in IVth quadrant as an independent driver variable. Road condition (F5), Intersection (F6) and Weather condition (F7) lie in the third quadrant having comparable driving and dependence power. These are the linkage variables.

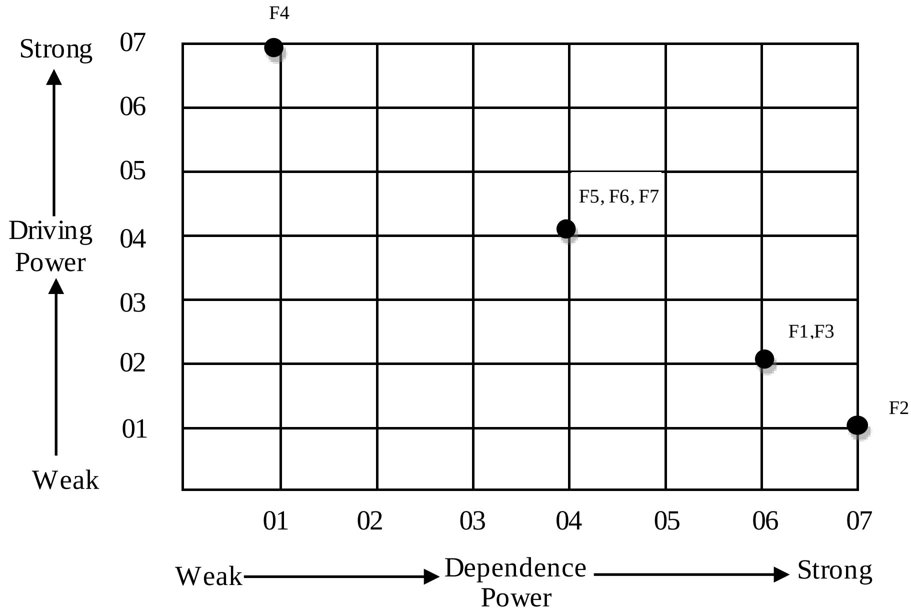

Fig. 2. Driving and Dependence Power Diagram

5. Conclusion

Road safety audit is a must in order to inculcate knowledge of traffic safety into the road network planning and design process. This would not only help in monitoring the safe usage and functioning of roads but also for ensuring prevention of road accidents. Road safety auditors are usually a team of qualified personnel who assess the safety performance and check for any probable causes of accidents that can be cured. This process ensures timely checking and mitigating possible risks to avoid any mishaps on roads.

The present study focuses on systematic analysis of accidents that have taken place in a span of three years on the selected case study stretch. Assessing the pattern of accidents, it concluded that methodical review of the accidents should be conducted before planning any strategy for accident mitigation.

The study has attempted implementation of TISM in order to institute linkage between variables causing road accidents. The schematic in the form of diagraph summarizes the observations of implementing TISM to the study variables. Out of the four levels in the diagraph, road feature is observed to be the most important variable on which all the other parameters depend. Classification of accident has the highest dependence on other variables in terms of occurrence. Road condition and weather condition are observed to be the variables with most number of connections and high level of interdependence forming the linkage variables. Road feature has the highest driving power whereas classification of accidents has the highest dependence power. If high attention is given to road features and road condition, one can promise accident free roads in India.

The present observations can augment a Road safety Audit in a positive way to analyse the situation based on the hierarchy as observed from the diagraph. Thorough understanding of the situation on any stretch of road would help the civil engineers to plan for safety measures accordingly. The observations of the study can form a guideline for road safety auditors to devise a strategy that minimizes accidents and helps in providing safer roads in the country.

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