ISM for analysing the safety of SRRMs

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Abstract- Interpretive structural modeling (ISM) is one of the well-established methodologies for identifying relationships among specific items, which define the problems of an issue. This approach has been increasingly used by various researchers to represent the interrelationships among various elements related to the issue. . In general, there exists a direct correlation between various customer receptivity aspects. Thus it makes more natural approach to this kind of problems. ISM approach starts with an identification of variables, which are relevant to the problem or issue. Then a contextually relevant subordinate relation is chosen. Having decided the contextual relation, a structural self-interaction matrix (SSIM) is developed based on customer receptivity of variables. SSIM is then converted into a reachability matrix (RM) and its transitivity is checked. Once transitivity embedding is completed, a matrix model is obtained. Then, the partitioning of the elements and an extraction of the structural model called ISM is obtained. In this paper, key concept of ISM approach is discussed about the hazardous situations of Steel Re Rolling Mills (SRRMs) in detail.

Index Terms- Interpretive structural modeling(ISM), structural self-interaction matrix (SSIM), Reachability matrix(RM) , , variable, modeling.

I. Introduction

Interpretive Structural Model analysis (ISM) is one of the well-proven and widely accepted system modeling approach for analysing the interrelationships between the variables influencing the system (Warfield, 1974; Sage, 1997). It is not only a diagnostic approach of the interconnections but also brings into consideration a system of directly and indirectly related elements, which maps the complex organisational issues (Warfield, 1976, Warfield, 1982, Sage. and Rouse1999). In general, there exists a direct correlation between various customer receptivity aspects. Thus it makes more natural approach to this kind of problems. In order to have a healthy customer relationship, receptivity aspects have to be leveraged. Management research is nourished with a plethora of ISM application in various fields (Agarwal, et al, 2006; Thakkar et al, 2008). In this regard, the factors influencing the external customer receptivity have been subjected to ISM. In the current study, thirteen aspects of hazardous situations of Steel Re Rolling Mills, which define the system under study, have been identified by referring direct information and then incorporating the opinion from experts of the organisation and academia (Bolonas, et al, 2005, Watson R, 1978).

II. Steel Re Rolling Mills and Interpretive Structural Models

One of the most abundant metals on earth is iron. It is made by different process in a furnace. We obtain different kinds of iron such as pig iron, wrought iron, sponge iron etc from its ore. Mild Steel (MS) is produced by melting and other process from which billets are produced first. These billets are further processed and tested to obtain structural steel.(Jacob P. George, pramod,2013).This process is done in steel re rolling mills(SRRMs). In India there are more than 1500 industries are working which produces different types of reinforced steel of different dimensions. . Iron is a transitional metal coming in the eighth group in modern periodic table. Its density is 7.874g/cc and melting point is 1538^0C (Donald et al, 2010).Iron is extracted from its ore like Magnetite (Fe_3O_4), Hematite (Fe_2O_3), Limonite FeO(OH).nH2O or siderite (($FeCO_3$)etc. (Cotton,et al,2008). Ores carrying very high quantities of hematite or magnetite (greater than ~60% iron) are known as "natural ore" or "direct shipping ore", meaning they can be fed directly into iron-making blast furnaces. Iron ore is the raw material used to make pig iron, which is one of the main raw materials to make steel. 98% of the mined iron ore is used to make steel. Indeed, it has been argued that iron ore is "more integral to the global economy than any other commodity, except perhaps oil". (Raghavan, 2004), Jacob P. George, V.R Pramod 2013,).

Interpretive Structural models(ISM) is defined as a process aimed at assisting the human being to better understand what an individual believes and to recognize clearly what he/she does not know. One of the essential functions is organisational. The information added (by the process) is zero. The value added is structural. The ISM process transforms unclear, poorly articulated mental models of systems into visible and well-defined models. Here the safety aspects of SRRM is analysing with ISM analysis. (Chidambaranathan S et al,2009)

ISM explores the dynamic influence of different elements which brings into consideration of a system of directly and indirectly related elements. It has three dimensions indicated by each letters. Dimension interpretive (I) is based on the judgment of a group of experts in that respective field. Collection of the perceptions of a group of experts decides whether and how the variables are interrelated. Second dimension (S) is structural, since on the basis of the relationship, an overall structure is extracted from the complex set of variables. Dimension (M) is modelling as it portrays the specific relationships of the variables and overall structure of the system under consideration. In other words, in ISM, I (interpretive) stand for the outcome of judgment, S (structural) stands for the extraction of outcome of a set of variables and M (model) stands for the graphical representation of the specific relationship and overall structure.

The study is conducted as a step-by-step procedure. (Bolonas et al. (2005),Raj T et al,2007)

III. HAZARDS IN SRRMS

The hazardous situations occur in SRRMs are due to certain aspects. These are given below

1) Road hazard (While coming / going to duty) high concentration of traffic during duty hours. Heterogeneous traffic, violation of traffic rules / speed limit road condition, condition of vehicle etc, we call as **road hazard**.

2) Vehicle's (brake, light. horn, tyres, air), start little early, maintain safe speed limit, follow traffic rules / give correct signals, use crash helmet, we call as due to **vehicle hazard.**

3) Major shops coke oven & Business Protection Plan (BPP): heat, smoke, dust, mobile equipment chemicals, fire and explosion etc. Blast furnace : liquid metal, gas, dust, conveyors, loco movement etc. Steel melting shop : liquid metal, explosion, cranes, other mobile equipment etc. Rolling mills : metal under rolling, heat, splinters, cobbles, hydraulics, cranes etc. Power plant : High tension electric. equipment, gas lines, heat, dust noise vibration etc. Foundries : heat, dust, explosion, chemicals etc, we call these are the kinds of **equipment hazard.**

4) Common hazards material handling manual : Posture, excess load, harmful contact by cranes : Defective tackles, slings, excess load, wrong signalling, working under load unskilled operator, defects in crane, improper / unauthorized handling ,say due to **handling hazard**.

5) Working at height medically unfit working without protection-Personal Protective Equipments (PPE)s, safety belt etc.) Unsafe scaffolding / excess loading unsafe access - Egress facilities overcrowding, working without permission, we say due to **access hazard.**

6)Working in confined space, working without written clearance, unauthorised entry, no protocol, inadequate supervision poor ventilation / no fresh air poor illumination, use of 230-V hand lamps, no emergency preparedness, working at or near gas lines, lack of skill / knowledge, working in empty stomach, not using safety appliances without protocol / clearance / shut down using improper tools, say **protocol hazard.**

7) Working with electrical equipment violation of shut down procedure no earthing / isolation using improper tools, lack of knowledge/ electrical work by non-electric persons, temporary / unsafe connections, safety appliances not used, say **electrical procedure hazard.**

8) Electrical hazards, electrical shock magnitude of shock depends on strength of leakage current duration of shock / current flow through body part, current path through body supply frequency position / condition of person in contact with live part, say **electric shock hazard.**

9) Electrical hazards standard means of protection earthing of metallic frame use of flexible cable having proper insulation using 230 V supply for hand lamps, lamp fittings, effectively earthed pendent, switches with rigid cord grip, say **electrical handling hazard.**

10) Electrical hazards standard means of protection inspection / testing of portable equipment / tools by experienced / qualified persons rating of circuit breakers / switches to handle fault current, use of cartridge fuse in place of wire fuse, periodic checking of earth continuity / earth resistance say **electrical protection hazard.**

11) Effect of current flow through body below 10 mA : mild sensation but not painful, 10 - 15 mA : Painful but muscles still in control, 15 - 20 mA : Muscle control affected, 20 - 40 mA : Muscle contraction, breathing problem, 40 - 80 mA : Rapid contractions of heart muscle, irregular heart beat (Fibrillation), possible death- above 100 mA : severe burns, muscular contractions, stoppage of heart - Certain death. Peak value of AC voltage is higher than the same in DC. Hence it is more dangerous, say **electric current hazard.**

12) Basic norms / standards knowledge about job safety training for all executives, non- executives including contactor workers and supervisors. Use of PPEs helmets, shoes, hand gloves, goggles / spectacles, aprons, screens / face shields, ear plugs, dust masks etc, say **awareness hazard.**

13) Basic norms / standards safe working procedure standard operating practices / standard operating maintenance (SOPs / SMPs) shut down procedures training and supervision, good house keeping access / walk ways, floors, proper illumination and ventilation, say **Operational hazard.**

IV. MODEL DEVELOPMENT PROCEDURE

From the above mentioned 13 numbers of hazards, we are able to analyze by the ISM techniques. The procedural steps of ISM are well documented in literature world at present. (Mandal and Deshmukh, 1994; Warfield, 1974; Thakkar et al., 2005, 2007). The model has been developed by the judgment of academicians and experts in that field. By brainstorming with various executives of different SRRM companies and academicians, the relationships among them have been identified.

Next procedure is to develop a Structural Self-Interaction Matrix (SSIM) which shows the direction of contextual relationships among the elements by symbolic interactions. To represent them in the table, four symbols are used in the matrix formation.(Pramod, V.R. and Banwet, D.K. (2010), (Rajesh K.S et al, ,2007)

V-The enabler i ameliorate/improve to achieve enabler j
A-The enabler j ameliorate/improve to achieve enabler i
X- The enablers i and j ameliorate/improve to achieve each other
O- The enablers i and j are unrelated.

A table is prepared (Table.1) below shows the Inter relationship between given 13 hazardous aspects.

Table. 1. Self- Interaction Matrix (SSIM)

	1 Road	2Vehicle	3Equipment	4Handling	5Access	6Protocol	7Electrica l Procedure	8Electric shock	9Elngectric al handling	10Electric	11Electric current	12Awareness	13Operational Hazard
1 Road Hazard	1	A	V	V	V	X	O	O	O	O	O	A	A
2 Vehicle Hazard		1	O	A	X	V	O	O	O	O	O	A	A
3 Equipment Hazard			1	A	A	X	X	X	X	X	X	A	V
4 Handling Hazard				1	A	A	V	V	V	V	V	A	V
5Access Hazard					1	A	A	A	A	A	A	V	X
6 Protocol Hazard						1	A	A	A	A	A	V	V
7 Electrical procedure Hazard							1	A	A	A	A	V	V
8 Electric shock hazard								1	A	A	A	A	V
9 Electrical Handling Hazard									1	V	V	A	V
10 Electric protection Hazard										1	V	V	V
11 Electric current Hazard											1	A	A
12 Awareness Hazard												1	A
13 Operational Hazard													1

4.1. INITIAL REACHABILITY MATRIX

Develop an Initial reachability matrix is the next step. Here SSIM has been converted into a metrics of binary elements named as Initial Reachability Matrix. This is achieved by appropriately assigning V, A, X and O by 1 and 0. In this regard, following rules have been applied.

1. If the (i, j) entry in the SSIM is V then substitute in the (i, j) entry in the reachability metrics as 1 and (j, i) entry as 0.
2. If the (i, j) entry in the SSIM is A then substitute in the (i, j) entry in the reachability metrics as 0 and (j, i) entry as 1.
3. If the (i, j) entry in the SSIM is X then substitute in the (i, j) entry in the reachability metrics as 1 and (j, i) entry as 1.
4. If the (i, j) entry in the SSIM is O then substitute in the (i, j) entry in the reachability metrics as 0 and (j, i) entry as 0.

Following the above rules, the initial reachability matrix has been developed(Table. 2)

Table 2. Initial Reachablity Matrix

	1 Road	2Vehicle	3Equipment	4Handling	5Access	6Protocol	7Electrica Procedure	8Electric shock	9Elngectric al handling	10Electric Protection	11Electric current	12Awareness	13Operational Hazard
1 Road Hazard	1	0	1	1	1	0	0	0	0	0	0	0	0
2 Vehicle Hazard	1	1	0	1	1	1	0	0	0	0	0	0	0

3 Equipment Hazard	0	0	1	0	0	1	1	1	1	1	1	0	1
4 Handling Hazard	0	1	1	1	0	0	1	1	1	1	1	0	1
5Access Hazard	0	1	1	1	1	0	0	0	0	0	0	1	1
6 Protocol Hazard	1	0	1	1	1	1	0	0	0	0	0	1	1
7 Electrical procedure Hazard	0	0	1	0	1	1	1	0	0	0	0	1	1
8 Electric shock hazard	0	0	1	0	1	1	1	1	0	0	0	0	1
9 Electrical Handling Hazard	0	0	1	0	1	1	1	1	1	1	1	0	1
10 Electric protection Hazard	0	0	1	0	1	1	1	1	0	1	1	1	1
11 Electric current Hazard	0	0	1	0	1	1	1	1	0	0	1	0	0
12 Awareness Hazard	1	1	1	1	0	0	0	1	1	0	1	1	0
13 Operational Hazard	1	1	0	0	1	0	0	0	0	0	1	1	1

3.1.1FINAL REACHABILITY METRICS

Here the transitivity are taken into account and establishes the relationship between various enablers. If a variable A leads to another variable B and if the variable B leads to a third variable C, as per the rule of transitivity A leads to C. In other words, if A leads to B and B leads to C, then A leads to C. Thus the final reachability matrix has been developed.(Table 3)

Table 3. Final Reachability Matrix

	1 Road	2Vehicle	3Equipment	4Handling	5Access	6Protocol	7Electrica Procedure	8Electric Shock	9Elngectric al handling	10Electric Protection	11Electric current	12Awareness	13Operational Hazard	Driving power
1 Road Hazard	1	**1**	1	1	1	0	0	0	0	0	0	**1**	0	**6**
2 Vehicle Hazard	1	1	0	1	1	1	0	0	0	0		**1**	**1**	**7**
3 Equipment Hazard	0	0	1	0	0	1	1	1	1	1	1	0	1	**8**
4 Handling Hazard	0	1	1	1	0	0	1	1	1	1	1	0	1	**9**
5Access Hazard	0	1	1	1	1	0	0	0	0	0	0	1	1	**6**
6 Protocol Hazard	1	0	1	1	1	1	0	0	0	0	0	1	1	**7**
7 Electrical procedure Hazard	**1**	0	1	0	1	1	1	0	0	0	0	1	1	**7**
8 Electric shock hazard	**1**	**1**	1	0	1	1	1	1	**1**	0	0	**1**	1	**10**
9 Electrical Handling Hazard	**1**	0	1	0	1	1	1	1	1	1	1	0	1	**10**
10 Electric protection Hazard	**1**	0	1	0	1	1	1	1	**1**	1	1	1	1	**11**
11 Electric current Hazard	**1**	0	1	0	1	1	1	1	0	0	1	0	0	**7**
12 Awareness Hazard	1	1	1	1	0	0	0	1	1	0	1	1	0	**8**
13 Operational Hazard	1	1	**1**	0	1	**1**	0	0	0	0	1	1	1	**8**
	10	7	**12**	6	10	**9**	7	7	6	4	7	9	10	102

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After finalizing the relationships while accounting transitivity, driving power and dependence of each enabler are also computed. They are respectively shown in the last column and last raw of Table 3. Driving power of an enabler is the total number of elements (including itself) it may help to achieve. In other words it is the total number of 1s in the raw. Similarly dependence of an enabler is the total number of elements (Including itself) that help to achieve it. In other words it is the total number of 1s in the column. These driving power and dependence helps to classify the enablers into four clusters namely autonomous, dependent, linkage and independent, (Raj T. and Attri R(2011).

Table 4. Iteration 1

Variable	Reachablity set	Antecedent set	Intersection set	Level
1	1,2,3,4,5,12	1,2,6,7,8,9,10,1112,13	(1,2,12)	**I**
2	1,2,4,5,6,12,13	1,2,4,5,8,12,13	1,2,4,5,12,13	**I**
3	3,6,7,8,9,10,11,13,	1,3,4,5,6,7,,8,9,10,11,12,13	3,6,7,8,9,10,11,13	
4	2,3,4,,7,8,9,10,11,13	1,2,4,5,6,12	2,4,	
5	2,3,4,5,12,13	1,2,5,6,7,8,9,10,11,13	2,5,13	
6	1,3,4,5,6,12,13	2,3,6,7,8,9,10,11,13	3,,6,13	
7	1,3,5,6,7,12,13	3,4,7,8,9,10,11	3,,,7	
8	1,2,3,5,6,7,8,9,12,13	3,4,8,9,10,11,12	3,8,12	
9	1,3,5,6,7,8,9,10,11,13	3,4,8,9,10,12	3,9,10	
10	1,3,5,6,7,8,9,10,11,12,13	3,4,9,10	3,9,10	
11	1,3,5,6,7,8,,11	3,4,9,10,11,12,13	3,11	
12	1,2,3,4,8,9,11,12	1,2,5,6,7,8,10,12,13	1,2,8,12	**I**
13	1,2,3,5,6,11,12,13	2,3,4,5,6,7,8,9,10,13	2,3,5,6,13	

Table 5, Iteration 2

Variable	Reachablity set	Antecedent set	Intersection set	Level
3	3,6,7,8,9,10,11,13,	3,4,5,6,7,8,9,10,11,13	3,7,8,9,10,11,13	
4	3,4,,7,8,9,10,11,13	,4,5,6	4,	II
5	3,4,5,13	5,6,7,8,9,10,11,13	4,5,13	
6	3,4,5,6,13	3,6,7,8,9,10,11,13	3,6,13	
7	3,5,6,7,13	3,4,7,8,9,10,11	3,5,,7	
8	3,5,6,7,8,9,13	3,4,8,9,10,11	(3,8,9)	
9	3,5,6,7,8,9,10,11,13	3,4,8,9,10	(3,8,9)	
10	3,5,6,7,8,9,10,11,13	3,4,9,10	3,9,10	
11	3,5,6,7,8,,11	3,4,9,10,11,13	3,11	
13	3,5,6,11,13	3,4,5,6,7,8,9,10,13	3,5,6,13	

Table 6, Iteration 3

Variable	Reachablity set	Antecedent set	Intersection set	Level
3	3,6,7,8,9,10,11,13,	3,5,6,7,8,9,10,11,13	3,7,8,9,10,11,13	**III**
5	3,5,13	5,6,7,8,9,10,11,13	5,13	
6	3,5,6,13	3,6,7,8,9,10,11,13	3,6,13	
7	3,5,6,7,13	3,7,8,9,10,11	3,5,,7	
8	3,5,6,7,8,9,13	3,8,9,10,11	(3,8,9)	**III**
9	3,5,6,7,8,9,10,11,13	3,8,9,10	(3,8,9)	**III**
10	3,5,6,7,8,9,10,11,13	3,9,10	3,9,10	
11	3,5,6,7,8,,11	3,9,10,11,13	3,11	
13	3,5,6,11,13	3,5,6,7,8,9,10,13	3,5,6,13	

Table 7, Iteration 4

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Variable	Reachablity set	Antecedent set	Intersection set	Level
5	5,13	5,6,7,10,11,13	5,13	
6	5,6,13	6,7,10,11,13	6,13	
7	5,6,7,13	7,10,11	5,,7	
10	5,6,7,10,11,13	10	10	IV
11	5,6,7,11	10,11,13	11	**IV**
13	5,6,11,13	5,6,10,13	5,6,13	

Table 8, Iteration 5

Variable	Reachablity set	Antecedent set	Intersection set	Level
5	5,13	5,6,713	5,13	
6	5,6,13	6,7,13	6,13	
7	5,6,7,13	7	7	V
13	5,6,13	5,6,13	5,6,13	

Table 9, Iteration 6

Variable	Reachablity set	Antecedent set	Intersection set	Level
5	5,13	5,6,13	5,13	VI
6	5,6,13	6,13	6,13	
13	5,6,13	5,6,13	5,6,13	**VI**

Table 10, Iteration 7

Variable	Reachablity set	Antecedent set	Intersection set	Level
6	6	6	6	**VII**

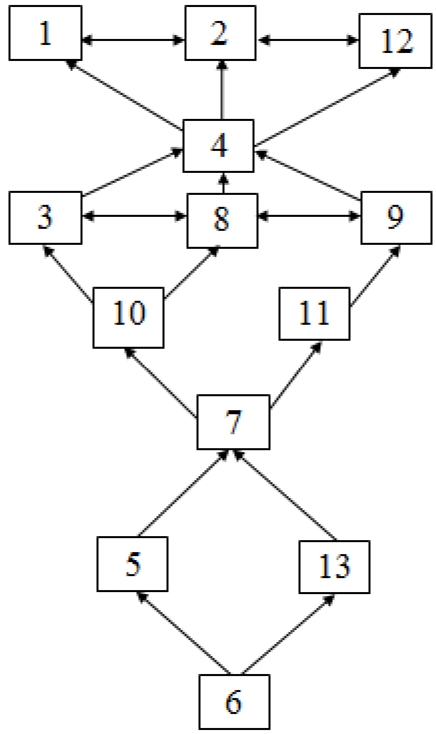

Figure 1. ISM for customer receptivity aspects

4.2. LEVEL PARTITIONS

From the final reachability metrics, the reachability and antecedent set (Warfield, 1974) of each enablers are located. Reachability set consists of a set of the element itself and other elements, which it may help to achieve, whereas, the antecedent set consists of a set of the element itself and the other elements, which may help achieving it. The variables, which are common in reachabilty set and antecedent set, are allocated at the intersection set. Thus antecedent set and intersection set are located. This led to locate the top-level element. The top-level element for each hierarchy is the elements in which antecedent set and intersection set are same in the ISM hierarchy. The top-level elements have been removed from the set for the formation of the next table. After those top-level elements are separated from the hierarchy, this process has been repeated to find the next level of element. This process has been continued till all levels of each element are found. These levels identified by this procedure have been utilized for to the formation of digraph. Reachability set, Antecedent set and Intersection set of level 1are shown in Table. 4. The subsequent iterations are shown in Tables 5 to 10. In Table 5 enablers 5, 6, 7, 8 11,12,16,17 and 18 are found at level 1. Thus they will be positioned at level 1. After removing them from Table 5 we get level II metrics. It is shown in Table 6.

V. MICMAC ANALYSIS

MICMAC analysis: Matrice d'Impacts croises-multiplication appliqúe an classment (cross-impact matrix multiplication applied to classification) is abbreviated as MICMAC. The main objective of MICMAC analysis is to analyse the drive power and dependence power of factors. (Mandal and Deshmukh,1994).MICMAC principle is based on multiplication properties of matrices26. It is done to identify the key factors that drive the system in various categories. Based on their drive power and dependence power, the factors, have been classified into four categories i.e. autonomous factors, linkage factors, dependent and independent factors.(Mandal and Deshmukh, 1994, Singh M.D etal,(2003, Attri R et al 2012)

The driving power and dependence of each of these enablers are imported from Table 11. Based on that initially a driver power-dependence diagram is constructed as shown in Table 11 .In order to have a better understanding, example of variable 1 is illustrated here. In Table 11, driving power is shown vertically and dependence is shown horizontally. Variable 1 is having driving power 6 and dependence 10. It is allocated in the appropriate position of (6, 10). Similarly other variables are also allocated. Cluster I includes autonomous variables. They have low driving power and low dependence. They can be isolated from the system. Cluster II consists of dependent variables that have low driving power and high dependence. Cluster III contains linkage variables that have high driving power and high dependence. Cluster IV consist of independent variables with high driving power and low dependent variables

Table 11.Driver power-dependence diagram

13													
12													
11				10									
10						9	8						
9						4							
8									12	13		3	
7							2,7,11		6				
6										1,5			
5													
4													
3													
2													
1													
	1	2	3	4	5	6	7	8	9	10	11	12	13

VI. CONCLUSION

Interpretive Structural Modelling (ISM), gives an ordered, directional framework for complex problems, and gives decision makers a realistic picture of their situation and the variables involved; variable 6, 13,5. The ISM process involves the identification of factors, the definition of their interrelationships; variables 1,2,12 and 3, 8, 9 , and the imposition of rank order and direction to illuminate complex problems from a systems perspective. ISM process transforms unclear, poorly articulated mental models of systems into visible and well defined models. These models help to find the key factor related to problem or issue. After identification of key factor or element, strategy may be developed for dealing issue. ISM method is understandable to a variety of users in the interdisciplinary groups, provides a means of integrating the diverse perceptions of participating groups, is capable of handling a large number of components and relationships typical of complex systems, is heuristic in terms of assessing the adequacy of model formulation, and leads to insights about system behaviour. ISM is also easy to use and communicable to a larger audience. These features of ISM approach has resulted into wide use of this approach.

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