Modelling the critical risk factors causing accidents at the construction sites of oil and gas projects

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Abstract. The accidents just don't occur; they are induced by the insecure practices, explosive atmospheres or both. The root causes of the accidents need to be identified and eliminated to raise the safety performance of the construction sector. The present study focusses on the factors causing accidents at the construction sites. Twelve critical factors are identified through the exhaustive survey of literature and views of experts from the academics and industries. The interpretive structural modelling methodology, a multi-criteria decision-making approach is used for establishing the contextual relationship among the identified elements, and a hierarchical model of the same is developed. Further, the crucial risk factors are obtained from the MICMAC analysis, based on the driving and dependence power of the elements. Two critical factors namely lack of knowledge on safety practices (R4), and insufficient communication between workers and supervisors (R8), are found to be the most significant as compared to other factors. An example of Indian oil and gas projects construction sites is exhibited to explain the real-world applicability of the suggested model. This article may guide academicians, and industry practitioners to understand the interrelationships among the identified factors and to eliminate the same to enhance the overall safety performance of the organization.

Keywords: Risk factors, Accidents at the construction sites, Safety, Interpretive structural modelling methodology, Oil and gas projects.

1. INTRODUCTION

An accident is an unplanned incident leading to damage of property, injury, or death of a person, it is caused due to the inefficient control of management on related work parameters (Pate-Cornell and Murphy, 1996; Zhou et al., 2007). The accidents statistics in the construction sector is very alarming all over the world. The mean value of accidents occurred in the U.K per year for 1000 workers is four times (approx) of the average of all the manufacturing sectors. It may be noted that, the Indian construction sector hires huge manpower, above 35 million people for the creation of Rs. 200 billion assets and the investment in the construction sector accounts for around 11 % of country's gross domestic product (Nair, 2014).The inefficiency of the management leads to four bunch of factors namely unsafe practices, unsafe working environment, job profile, and personal factors (Rowlinson, 1997; Liske et al., 1993). Working in oil and gas construction projects is very hazardous and challenging and it is mainly due to the hostile working atmosphere (Chan, 2011). The occupational accidents are caused due to the stress caused by several risk factors. Fatigue is one of the important elements that causes work deficiency which could be equal to or more than 0.1 % alcohol in blood, which is considered as unsafe for driving a crane, or actuating any critical equipment. It is considered four times more dangerous than drugs and alcohol for causing the accidents at the workplace (Lamond and Dawson, 1999). The potential accidents at the sites can be avoided by proper identification and assessment of risk factors causing causalities at sites, which falls under the segment of risk management. It is the role of the mangers of the organization to set up proper guidelines for the effective accident control (Tweeddale, 2003; Jackson and Loomis, 2002). There is tremendous need of effective ‘safety management programs’ implementation which depends heavily on the perception, proper evaluation of risk intensity, and its control (Chan, 2011). A safety audit checklist is the most import tool for identifying the risk factors and hazards caused by them effectively. This method considers all the risk factors with equal importance (Khan and Abbasi, 1998). The checklists need to be relevant to the culture so that the decision makers can identify, evaluate and rank the accident causing parameters (Hsu et al., 2008).

There is a lack of knowledge in understanding the significance of various risk factors of the sector (McLain and Jarrell, 2007; Cox and Tait, 1998) and this study focusses on the identification and modelling of the most significant risk factors causing accidents at the construction sites of oil and gas projects through extensive literature survey & opinions of experts from the academia and industry. Not much work is carried out in this area and this research guides the managers in eliminating the same and providing safe working environment. This article is arranged in the following sequence- section 2 is the literature survey, which presents information on the overview of the risk management at construction sites, applications of interpretive structural modelling methodology, and identifies the crucial factors which cause accidents. Section 3 covers the research methodology used in the study. In section 4 the case study is described, and section 5 comprises of results and discussion. Conclusion and future scope of the investigation are presented in section 6.

2. LITERATURE SURVEY

The safety of workers in the construction sector is a great matter of concern. It is the most vulnerable element of the disorganized labour in India. It is found that about 16.5 % workers get injured at the construction sites and the fatal accident rate is about 4-5 times of the manufacturing industries across the country (Nair, 2014). In the area of safety of workers towards accidents, Reason (2000), and Haslam et al. (2005) developed a complex model of interactions among the place of work, materials and machinery, work team and concluded that hazard ignorance and inefficient training are the risk factors due to the human tendencies or errors. Well trained workforce also can make mistakes occasionally which lead to accidents (DiMatttia et al., 2005; Reason, 2000). The fatigue of the workers leads to human errors and it is identified as the most important risk factor (Folkard and Tucker, 2003). Tam et al. (2004) and Zeng et al. (2008) used methodology which was un-standardized, that made the comparison of complex risk factors. Gyi et al. (1998) and Donoghy (2009) stated that the attitude of the construction worker towards the safe practices and usage of the unsafe machinery cause accidents. The present study evaluates the crucial risk factors and their interdependence using interpretive structural modeling methodology.

This segment is split into two sections, first is the overview of the interpretive structural modeling methodology and the second one is the identification of critical factors causing accidents in the construction of oil and gas projects, which are discussed below-

2.1 Overview of the Interpretive Structural Modelling (ISM) Methodology

Many researchers established interrelationships among the identified factors or variables of a problem or an issue under study, using ISM approach. Some of the papers are summarized in Table 1 and explained subsequently in this section.

Ojo et al. (2014) studied drivers and obstacles in the implementation of GSCM practices in Nigerian construction industries. It is concluded that lack of public awareness, lack of knowledge and environmental impacts, a weak commitment by the top management and lack of legal enforcement and government are the significant barriers. Toktaş-Palut et al. (2014) investigated the effects of barriers and benefits of e–procurement systems for books and stationery sector supply chain using ISM methodology after that the structural equation modeling (SEM) is used for the validation purpose. Inadequate IT infrastructure of suppliers/business partners is found to be the most important barrier, on the other hand, the most significant benefit is integrated information sharing. In the occupational safety and health (OSH) segment, Cagno et al. (2014) modeled OSH factors relevant to small and medium-sized enterprises (SMEs). Out of eight factors, three factors namely policy (company culture and economic ties), business and local characteristics and labor management are found to have the highest driving power and a factor namely risk level is found to have the greatest dependence power. Hsu et al. (2015) identified critical driving factors influencing the performance of university technology transfer. To establish the relative significance among the drivers, fuzzy Delphi method, ISM approach, and the analytic network process (ANP) are employed. It is inferred that two drivers' namely human capital and institutional resources are the most significant drivers for the university technology transfer. Beikkhakhian et al. (2015) identified, evaluated and ranked the criteria for agile suppliers. It is discovered that variables namely delivery speed, cost minimization, and lead time reduction are found to have the highest driving power. Then, a fuzzy hierarchical method is used to weight the criteria then fuzzy TOPSIS approach is employed to rate the six suppliers. It is concluded that the factors with high driving power had greater weight in AHP model. Ren et al. (2015) identified and ranked the barriers influencing the sustainable shale gas revolution in China using fuzzy ANP and ISM methodology. It is concluded that the restrictions namely lack government guidelines and support, lack of standards and regulations, lack of core technologies are the most significant barriers. Zhang et al. (2015) evaluated the interrelationship among the factors influencing network reconfiguration, and the speediness & security of generating items are prioritized. Luthra et al. (2015) analyzed the relationship among the elements to implement GSCM towards sustainability. The scarcity of natural resources is found to have the most influential power. Ravi (2015) evaluated the interactions among the eco-efficiency barriers in the electronics packaging industry. It is found that restrictions namely lack awareness about environmental issues, lack of top management commitment, short-term perspectives of decision making are the most significant. Rajaprasad and Chalapathi (2015) studied the factors influencing the implementation of occupational health safety assessment series (OHSAS) 18001 in Indian construction industries. It is found that management commitment and safety policies are the most influential factors. Yadav and Barve (2015) evaluated critical success factors for the responsive humanitarian supply chain. It is concluded that the policies of the government and the structure of the organization are found to be the most significant.

Table 1: Summary of papers published using the interpretive structural modelling (ISM) methodology

S. No	Author (s)	Year	Country	Industry/ Sector	Problem/Application area
1	Ojo et al.	2014	Nigeria	Construction	Barriers in implementing GSCM practices in Nigeria
2	Toktaş-Palut et al.	2014	Turkey	Books and stationery	Investigation of barriers and benefits of e-procurement system
3	Cagno et al.	2014	Italy	OSH	Occupational safety performance for SMEs
4	Hsu et al.	2015	Taiwan	Technology transfer	Critical drivers affecting the performance of university technology transfer
5	Beikkhakhian et al.	2015	Iran	Agile suppliers	Evaluation of agile suppliers
6	Ren et al.	2015	China	Oil and gas	Barriers affecting the sustainable shale revolution
7	Zhang et al.	2015	China	Network reconfiguration	Relationships among the factors affecting network reconfiguration
8	Luthra et al.	2015	India	Mining	Interactions among CSF's to implement GSCM towards sustainability
9	Ravi	2015	India	Electronic packaging	Interactions among eco-efficiency barriers
10	Rajaprasad and Chalapathi	2015	India	Construction	Factors influencing the implementation of OHSAS 18001
11	Yadav and Barve	2015	India	Humanitarian supply chains	Critical success factors of humanitarian supply chains

2.2 Critical Factors Causing Accidents at the Construction Sites of Oil and Gas Projects.

The twelve most critical accidental factors are identified through exhaustive literature review and opinions of experts, which are shown in the Table 2.

Table 2: List of critical risk factors causing accidents at construction sites of oil and gas projects.

S. No	Risk factors	Author(s)
1	Fire or explosion	Abdelhamid and Everett (2000), Bültmann et al. (2002); Chan (2011); Dawson and Reid (1997); DiMattia et al. (2005); Donaghy (2009); Falconer and Hoel (1996); Folkard and Tucker (2003); Gander et al. (2000); Gyi et al. (1998); Haslam et al. (2005); Hsu et al. (2008); Jackson and Loomis (2002); Koehn et al. (1995); Lamond and Dawson (1999); Laukkanen (1999); Liske et al. (1993); Lubega et al. (2000); Nachreiner (2000); Pate-Cornell and Murphy (1996); Pipitsupaphol and Watanabe (2000); Reason (2000); Rowlinson (1997); Tam et al. (2004); Toole (2002); Van thuyet et al. (2007); Wilson and Koehn (2000), Zeng et al. (2008); Zhou (2007).
2	Defective equipment	
3	Emotional disturbances	
4	Lack knowledge on safety practices	
5	Fatigue	
6	Hostile environment (Noise, weather, dust etc.)	
7	Workers failure in practicing safety norms	
8	Insufficient communication between workers and supervisors	
9	Improper handling of equipment's	
10	Non-usage personal protection equipment	
11	Incorrect workplace layout	
12	Usage of low construction technology	

3. RESEARCH METHODOLOGY

The purpose of the present study is to develop a new conceptual structural model of critical factors causing accidents at the construction sites of oil and gas projects. The outcomes of this research will guide the organizations to review their structure towards safety programs. The ISM tool, a multi-criteria decision making (MCDM) approach is employed to build the association between the identified factors and to find the most substantial parameter. The introduction to ISM methodology and steps included in the same are detailed in the subsequent section.

3.1 Introduction to ISM Methodology

ISM uses an interpretive approach (based on the judgments of the experts from the industry and academia) for establishing the contextual relationship among the different and directly related identified factors of an issue or a problem (Sage, 1977). It is an application of simple notations of graph theory used to explain the complex pattern of relationships (Ravi and Shankar, 2005). It converts unclear, poorly articulated interpretive models into visible, correctly defined models useful for many applications by imposing order and direction to the complex relationships (Sage, 1977). This methodology is widely used by the researchers for exploring the direct and indirect association among the identified parameters of various industries in a simplified way. It provides interpretation of the fixed object and facilitates to identify structure within the system (Pramod and Banwet, 2015).

The steps involved in ISM methodology are listed below (Kannan et al., 2009)-

Step 1: the crucial factors causing accidents are identified and listed.

Step 2: a relationship is established among all the identified safety challenges.

Step 3: to establish a pair-wise relationship among barriers, a structural self-interaction matrix (SSIM) is formulated.

Step 4: from the SSIM a reachability matrix is developed, and the same is checked for the transitivity. This is an underlying supposition in the ISM tool that defines if a barrier 'X' is related to 'Y' and 'Y' is related to 'Z' then 'X' is similar to 'Z'.

Step 5: the final reachability matrix obtained from step 4 is portioned into different levels.

Step 6: from the final reachability matrix of final contextual relationships among the factors, a directed graph (diagraph) is drawn and transitive links are removed from the same.

Step 7: by replacing the nodal elements with the statements, the developed diagraph is transformed into ISM model of safety issues.

Step 8: the developed model is reviewed and checked for any conceptual inconsistencies.

All the steps of ISM approach discussed above are shown in Figure 1.

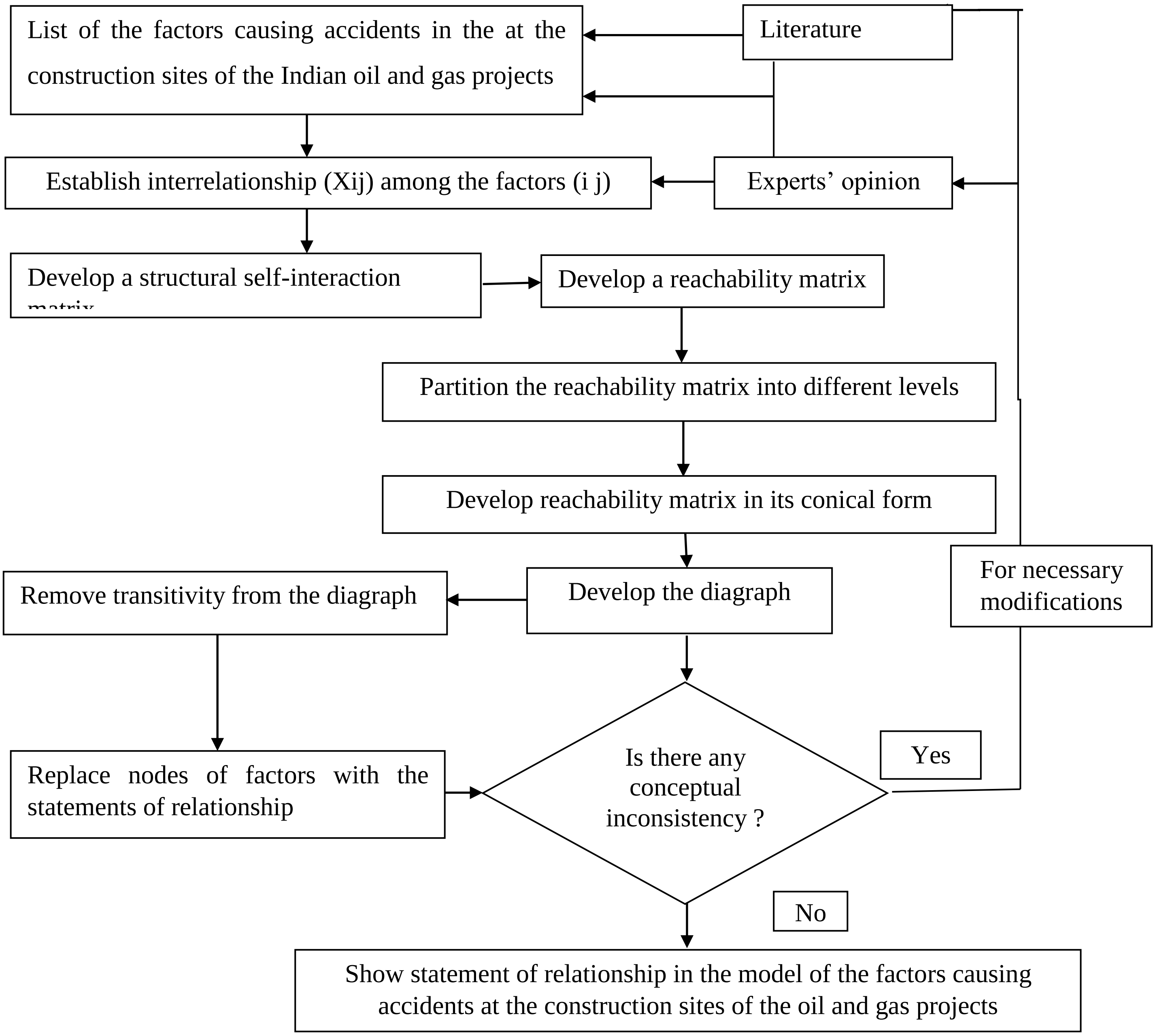

Figure 1. Flow chart for preparing the ISM model of risk factors, modified from Kannan et al. (2009).

4. CASE STUDY

XYZ is a construction company offering construction services to both offshore and onshore oil and gas projects, situated in the western part of India. It is committed to implementing safety programs for the workers at the construction sites. In this paper, the critical challenges to the workforce safety programs are identified and modeled. The ISM methodology is applied to the sector being studied. Various steps leading to the formulation of the ISM model are discussed below.

4.1 Identification of the Significant Accident Causing Factors at the Construction Sites of Oil and Gas Projects.

The twelve factors are identified through literature survey and opinions of experts from the academia and industries.

4.2 Development of Structural Self-Interaction Matrix (SSIM)

The structural self-interaction matrix is formulated from the interrelationship among the twelve significant factors shown in Table 3. For interpreting, the relationship following four symbols were used to understand the direction of relationship among the identified elements.
O – no relation between the factors
X – factor i and j will help to achieve each other
V –factor i will help to achieve factor j.
A – factor j will help to achieve factor i.

4.3 Reachability Matrix

The initial reachability matrix shown in Table 4 is developed from the SSIM using the following rules-

a. If the entry of (i, j) in the SSIM is 'V' then the (i, j) value in the reachability matrix will be '1' and the (j, i) value becomes '0'.
b. If the entry of (i, j) in the SSIM is 'A' then the value of (i, j) in the binary matrix becomes '0' and the value of (j, i) will be '1'.
c. If the entry of (i, j) in the SSIM is 'X' the value of (i, j) and (j, i) in the reachability matrix will be '1'.
d. If the entry of (i, j) in the SSIM is 'O' then the value of (i, j) and (j, i) in the binary matrix becomes '0'.

The final reachability matrix is obtained from the initial reachability matrix by adding transitivity to the latter manually, is shown in Table 5.

Table 3: Structural self-interaction matrix (SSIM) of barriers

S.N	Critical barriers	12	11	10	9	8	7	6	5	4	3	2
1	Fire or explosion	A	A	A	A	A	A	A	A	A	A	A
2	Defective equipment	O	O	O	X	A	X	A	X	A	A	
3	Emotional disturbances	A	A	O	V	X	X	A	X	X		
4	Lack knowledge on safety practices	V	V	V	V	V	V	O	V			
5	Fatigue	A	A	X	X	X	X	A				
6	Hostile environment (Noise, weather, dust etc.)	A	A	A	X	A	O					
7	Workers failure in practicing safety norms	O	O	V	V	A						
8	Insufficient communication between workers and supervisors	V	V	V	V							
9	Improper handling of equipment's	O	A	A								
10	Non-usage personal protection equipment	A	O									
11	Incorrect workplace layout	V										
12	Usage of low construction technology											

Table 4: Initial reachability matrix for the critical factors

S.N	Critical barriers	1	2	3	4	5	6	7	8	9	10	11	12
1	Fire or explosion	1	0	0	0	0	0	0	0	0	0	0	0
2	Defective equipment	1	1	0	0	1	0	1	0	1	0	0	0
3	Emotional disturbances	1	1	1	1	1	0	1	1	1	0	0	0
4	Lack knowledge on safety practices	1	1	1	1	1	0	1	1	1	1	1	1
5	Fatigue	1	1	1	1	1	0	1	1	1	1	0	0
6	Hostile environment (Noise, weather, dust etc.)	1	1	1	0	1	1	0	0	1	0	0	0
7	Workers failure in practicing safety norms	1	1	1	0	1	0	1	0	1	1	0	0
8	Insufficient communication between workers and supervisors	1	1	1	0	1	1	1	1	1	1	1	1
9	Improper handling of equipment's	1	1	0	0	1	1	0	0	1	0	0	0
10	Non-usage personal protection equipment	1	0	0	0	1	1	0	0	1	1	0	0
11	Incorrect workplace layout	1	0	1	0	0	1	0	0	1	0	1	1
12	Usage of low construction technology	1	0	1	0	1	1	0	0	0	1	0	1

Table 5: Final reachability matrix for the critical risk factors

S.N	**Critical barriers**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Dr.P**
1	Fire or explosion	1	0	0	0	0	0	0	0	0	0	0	0	1
2	Defective equipment	1	1	0	0	1	0	1	0	1	0	0	0	5
3	Emotional disturbances	1	1	1	1	1	0	1	1	1	0	0	0	8
4	Lack knowledge on safety practices	1	1	1	1	1	0	1	1	1	1	1	1	11
5	Fatigue	1	1	1	1	1	0	1	1	1	1	0	0	9
6	Hostile environment (Noise, weather, dust etc.)	1	1	1	0	1	1	0	0	1	0	0	0	6
7	Workers failure in practicing safety norms	1	1	1	0	1	0	1	0	1	1	0	0	7
8	Insufficient communication between workers and supervisors	1	1	1	0	1	1	1	1	1	1	1	1	11
9	Improper handling of equipment's	1	1	0	0	1	1	0	0	1	0	0	0	5
10	Non-usage personal protection equipment	1	0	0	0	1	1	0	0	1	1	0	0	5
11	Incorrect workplace layout	1	0	1	1*	0	1	0	1*	1	0	1	1	8
12	Usage of low construction technology	1	0	1	0	1	1	0	0	0	1	0	1	6
	Dependence Power	12	8	8	4	10	6	6	5	10	6	3	4	

4.4 Level Partitions

From the final reachability matrix shown in Table 5, the reachability and antecedent sets for each critical element is obtained. The reachability set of an individual factor consists of other elements and itself, which it may help to achieve and the antecedent set comprises of the factors themselves and the other factors, which may assist in making it. The intersection of both these sets is obtained for all the other critical parameters. A factor having both reachability and intersection sets same secures the top level in the hierarchy. This parameter is driven by all other factors and doesn't affect other factors (Kannan et al., 2009). The high-level factors are separated from the remaining ones, and this procedure is repeated for all other factors for identifying the factors falling in each level. These levels help in building the diagraph and the final ISM model (Singh and Kant, 2008). Table 6 shows the reachability set, antecedent set, intersection set, initial, final levels, and the level evaluation process of all the twelve risk factors completed in five iterations.

Table 6: Level partitions of the reachability matrix. Iteration I to Iteration V

S.N	**Reachability Set**	**Antecedent Set**	**Intersection**	**Level**
1	1	1,2,3,4,5,6,7,8,9,10,11,12	1	I
2	1,2,5,7,9	2,3,4,5,6,7,8,9	2,5,7,9	II
3	1,2,3,4,5,7,8,9	3,4,5,6,7,8,11,12	3,4,5,7,8	III
4	1,2,3,4,5,7,8,9,10,11,12	3,4,5	3,4,5,11	V
5	1,2,3,4,5,7,8,9,10	2,3,4,5,6,7,8,9,10,12	2,3,4,5,7,8,9,10	II
6	1,2,3,5,6,9	6,8,9,10,11,12	6,9	III
7	1,2,3,5,7,9,10	2,3,4,5,7,8	2,3,5,7	III
8	1,2,3,5,6,7,8,9,10,11,12	3,4,5,8	3,5,8,11	V
9	1,2,5,6,9	2,3,4,5,6,7,8,9,10,11	2,5,6,9	II
10	1,5,6,9,10	4,5,7,8,10,12	5,10	III
11	1,3,4,6,8,9,11,12	4,8,11	11	V
12	1,3,5,6,10,12	4,8,11,12	12	IV

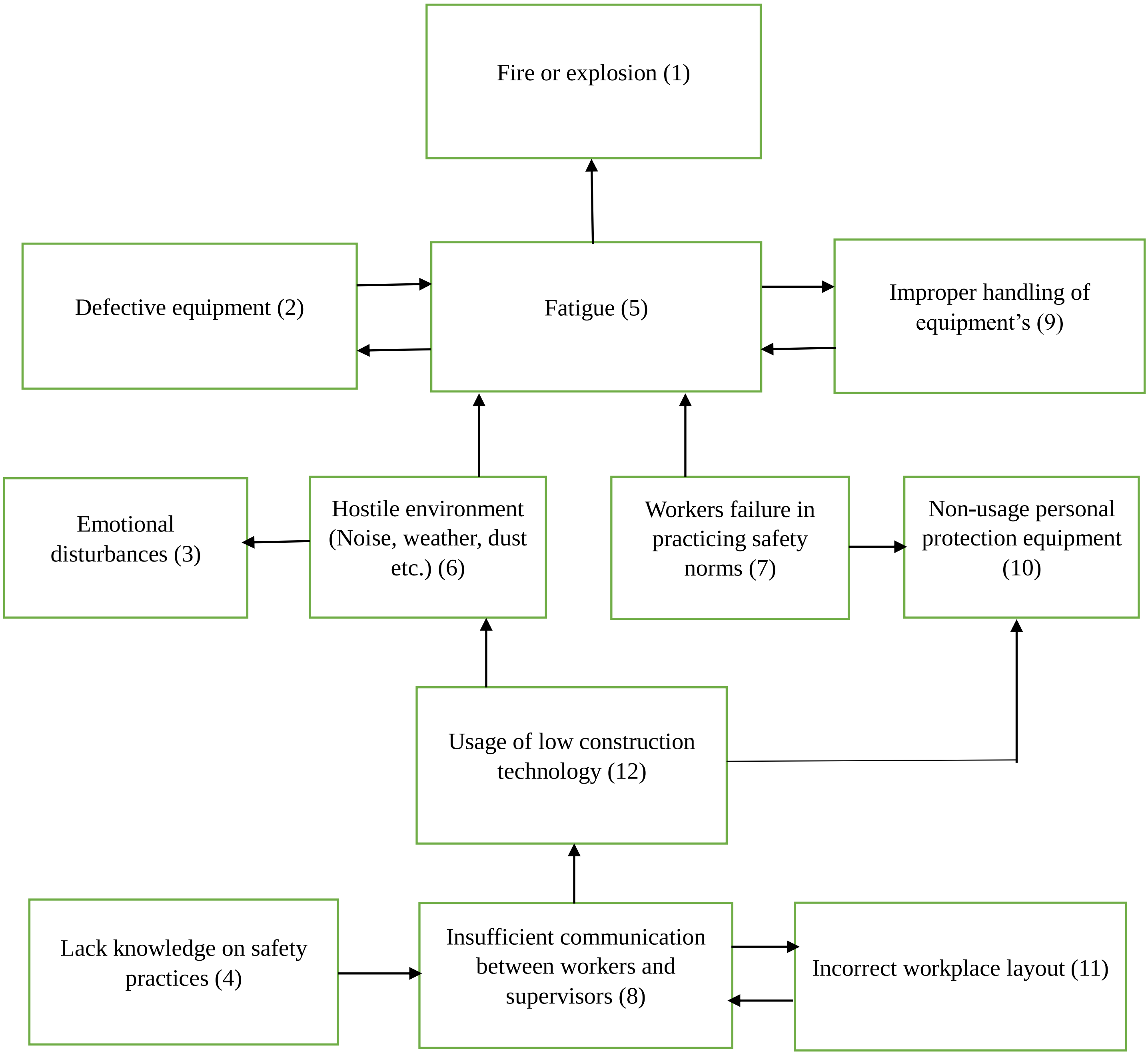

Figure 2: ISM model of factors causing accidents at the construction sites of oil and gas project.

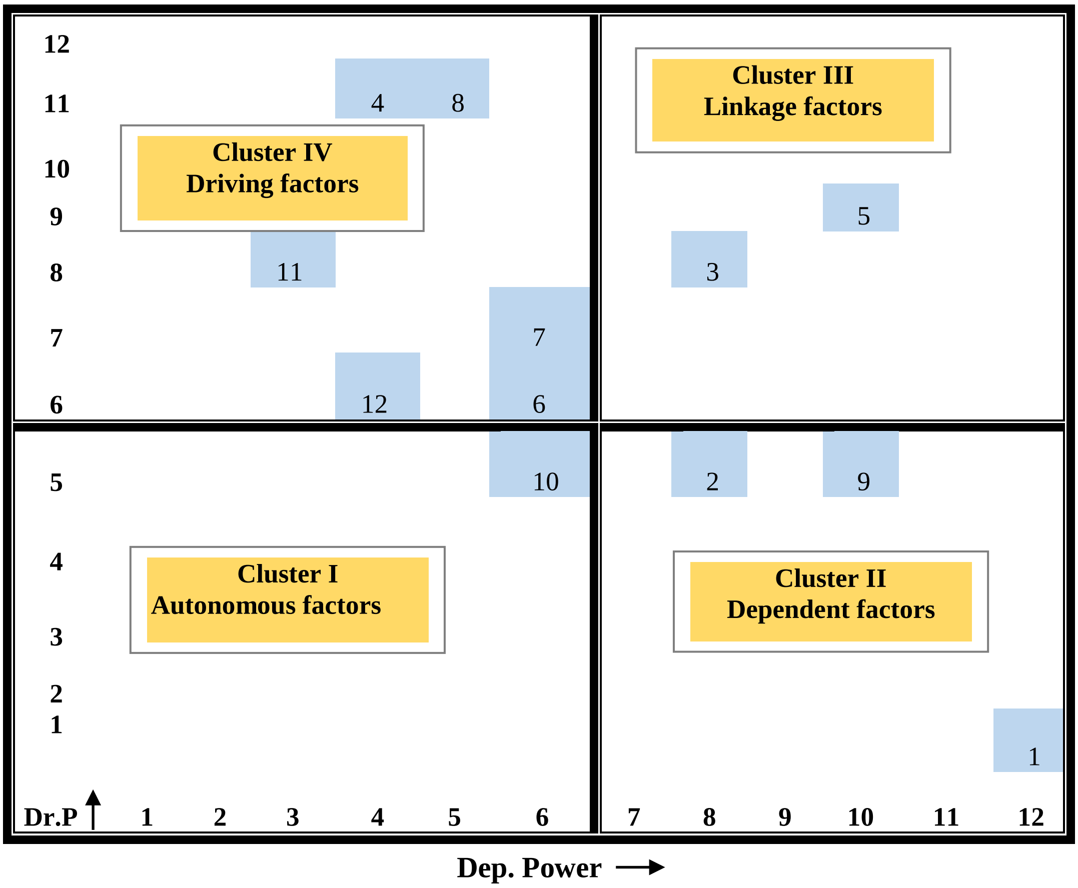

Figure 3: Driving and dependence power diagram of risk factors

4.5 Formation of the ISM Model

From the final reachability matrix (Table 5) a structural model is developed. For showing the relationship between two barriers i and j, an arrow is shown from i to j and the generated diagram is called as the initial diagraph. For drawing, the final diagraph, the transitivity's from the original diagraph are removed. Later, this diagraph is transformed into an ISM model as illustrated in Figure 2.

4.6. MICMAC Analysis

In the present study MICMAC analysis is used to identify the critical risk factors causing accidents at the construction sites of oil and gas projects based on the driving and dependence power, which is calculated from the final reachability matrix.

The identified critical factors are classified into four clusters, which are explained below-

Autonomous- these are the factors with a weak driving and dependence power.

Dependent- these are the factors with a weak driving power and a high reliance power.

Linkage- these are the factors with a great driving and dependence power.

Driving or independent- these are the factors, with high driving and weak dependence power (Kannan et al., 2009; Sharma et al., 1995). The driving and dependence influence diagram (power matrix) of the risk factors is shown in Figure 3.

5. RESULTS AND DISCUSSIONS

An ISM model of the twelve critical challenges is shown in Figure 2 indicating their hierarchical levels. The top factor of the structural model in the first level namely fire and explosion (R1) is found to be the least significant as compared to other eleven elements. Hence, this parameter demands less attention. At the second level, there are three factors namely defective equipment (R2), fatigue (R5), and improper handling of equipment's (R9). The elements of this level influence the parameters of the first tier. In the third level, there are four factors namely emotional disturbances (R3), hostile environment (noise, weather, dust etc.) (R6), workers failure in practicing safety norms (R7), and non-usage personal protection equipment (R10). These factors drive the factors above this level. In the fourth level there is a single significant factor namely usage of low construction technology (R12), and in the bottom level there are three most important risk factors which demand the maximum attention, namely Lack knowledge on safety practices (R4), Insufficient communication between workers and supervisors (R8), and Incorrect workplace layout (R11). These three critical risk factors need to be eliminated to implement a successful safety program for the workers at the construction sites.

The MICMAC analysis is shown in Figure 3, highlighting the cluster I (autonomous factors) which has one factor namely non-usage of personal protection equipment (R10) having weak dependence and driving power. On the other hand, there are two factors in cluster II (dependent factors) namely defective equipment (R2), and improper handling of equipment's (R9) both having high dependence and weak driving power. The cluster III (linkage factors) comprises of the factors having high driving and dependence power, and two factors that fell in this segment are emotional disturbances (R3), and fatigue (R5). There are six most significant factors which fall in the cluster IV (driving factors) namely lack of knowledge on safety practices (R4), insufficient communication between workers and supervisors (R8), and Incorrect workplace layout (R11), workers failure in practicing safety norms (R7), usage of low construction technology (R12), and hostile environment (noise, weather, dust etc.) (R6). The cluster IV reflects the elements with strong driving power but weak dependence power and these factors demand the maximum attention of the decision makers for their elimination.

6. CONCLUSION AND FUTURE SCOPE

After agriculture, the construction sector is the largest economic activity in India. A large volume of workers are exposed to the working environments accidental risks and occupational health problems in the sector. There are regulations about the working atmosphere for the safety of the workers, but they are found to be not that effective. The top construction companies of the country are taking significant efforts to provide safety to their manpower, but still there is a rise in the number of casualties. The solution to this problem is the 'safety awareness'. The safety is at the site is every person's responsibility and the proper attention should be given to the same. Workers should be encouraged to practice safety norms. The management of the organization should identify the potential risks which may turn into accidents, and the same may be eliminated at the earliest (Nair, 2014). In the present study, a structural model of twelve important factors is shown in Figure 2 to identify the significant risk factors causing accidents at the construction sites of the Indian oil and gas projects using ISM approach. The managers of the organization have to eliminate the same to achieve the peak safety performance in the focused stream. The critical factors were iterated in five levels. The three most influential parameters in the descending order of driving power magnitudes are- lack knowledge on safety practices (R4), insufficient communication between workers and supervisors (R8), both are having the highest driving power of 11, and a factor namely fatigue (R5), is found to have the driving power of magnitude 9.

It may be noted that each organization has its individual policies and evaluation parameters for the analysis of risk factors causing accidents. Due to this the criteria of weights vary significantly from organization to organization and the relevant results are valid only for the case company and cannot be made generic to all other sectors. The investigation of the relevant criteria for risk factors causing accidents at the construction sites of Indian oil and gas projects using MCDM approach helps in providing a vital perspective concerning the interrelationship among the identified variables to form guidelines for the researchers and practitioners.

For using the ISM methodology which is utilized in the present case study, the person should possess in-depth knowledge of the method and needs to be sufficiently trained to interpret the obtained data, and computer facilities are required to apply this tool efficiently to the identified issue (Sushil, 2012). The relation between the parameters totally depend the on the judgments of the persons knowledge, and the inputs given by the experts could be biased (Jhole and Babu, 2014). To overcome these limitations and to improve the accuracy of the model or for the purpose of validation, integrated approach may be used (Gardas et al., in press). Tools which can be employed along with the ISM approach are interpretive ranking process (IRP), technique for order preference by similarity to ideal solution (TOPSIS), analytic hierarchy process (AHP), analytic network process (ANP), decision making trial and evaluation laboratory (DEMATEL), structural equation modelling (SEM), total interpretive structural modelling (TISM) (Gardas et al., 2015).

In this study, twelve critical barriers are considered; however, there may be other factors that are omitted in this model but may affect the safety performance. The inclusion of more factors in other studies will yield better results. In future, authors would like to validate this model using a structural equation modelling methodology.

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