Hazard identification and risk assessment for material handling in construction industry

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ABSTRACT

Materials handling is the art and science involving the moving, packaging and storing of substances in any sector. But in the construction sector materials handling is inefficient because of uncertainty during conceptualization, real time co-ordination problems and lack of control in the field due to its dynamic nature. It is one of the leading causes of accidents in construction industries, in spite of adopting numerous safety management activities. Hazard identification and risk assessment involves identification of adverse activities that leads to a hazard, the analysis of hazard assessment by which this undesirable activities could occur and the evaluation of its extent and effects quantitatively as well as qualitatively. It is used to control the risk by implementing mitigation measures before start of the work to avoid accidents. HIRA helps to become proactive rather than just reactive. In this work HIRA was applied for various activities of material handling such as material handling by dumper, by material hoist/tower crane/winches, by mobile cranes and manual material handling its various hazards, risks and its evaluation of different parameters were studied. The suitable control measures were applied to overcome these risks, and the results shown the better performance of these control measures. The results also notified by means of Risk matrix. This study reveals that HIRA in material handling was effectively reduced hazardous events in the construction industry.

Key words: Construction, Material handling, Hazards & HIRA.

Abbreviations: HIRA, Hazard identification and risk assessment; RPN, Risk priority Number fault tree analysis (FTA), Fault tree analysis; HAZOP, hazard and operability evaluation; HACCP, hazard analysis and critical control points; FMEA, failure mode effective analysis.

1. INTRODUCTION

Generally construction field operations are incompetent for the storage and handling of materials. Material handling is a basic activity in construction industry, which involves the movements of materials during the operations. The aim of material handling is to have optimum movements by shortest route without any damage. Material handling systems may be effectively managed by changing the layout [1].Construction accidents cost about 6% of the total cost, in which one-third of cost spend for loss of life in the construction and maintenance sites due to improper management of material handling [2].

Construction project performance can be potentially affected by an inappropriate handling and management of materials [3]. It causes elevated handling cost of products, unwanted confusion in loading/unloading, engaging additional workers, stock out on parts and supplies, not within the limits of statutory requirements, bulk scrap and deficient flows, improper storage of products, overload action, unwanted indirect and labor cost, idle cube storage, frequent idle times, polluted amenities and unwanted employees [4]. It also influences on the total project cost, duration and the standard [5]. Constraints on storage areas, site logistics with regards to materials handling and distribution and ordering and delivery of materials to the construction site are the major problems which affects the material handling activities. Appropriate safety management system and procedures of material handling should be adopted for the construction industry to avoid accidents. Safety management system at construction sites promotes for a goal setting, planning, and evaluating results while it is associated with the normal operations of the organization [6]. A safety management system produces a proper methodology for the identification of hazard and controlling the risks [7].

Hazard identification and risk analysis (HIRA) is a collective term that encompasses all activities involved in notifying hazards and evaluating risk at worksites, throughout the entire duration, to make various that risks to workers, the general peoples or the surrounding. A HIRA is a risk control tool used to identify and evaluate the hazards lead to various risks in terms of frequency and the magnitude of the potential impact. It is not intended to be used as a prediction tool to determine which hazard will cause the next emergency [8]. It is used for finding the process activities result a hazard, evaluation of its level, extent and possibility of destructive effects. It is a widely accepted risk assessment tool contributes greatly towards enhancement in the safety of complex processes and tools [9].

Materials handling procedures essentially incorporating with resource flow have been criticized for not using the suitable available methods and techniques. This led to proper studies of available techniques [10]. Several studies have been carried out by several researchers [11-15] on safety with material handling. A case study was conducted to demonstrate a profit/expenditure ratio of 5.7, making better consideration to materials management [16]. Many researchers have discussed the material flow concept in the process and highlighted the issues of materials management such as; inappropriate storage [17], necessity for bulk storage capacity [18], difficulties during transportation and delivery of materials [19]. Other issues include; manual material handling and not meeting the regulations [20]. It was evident that health and safety training incorporated to the workers was effective with the intention of identification and evaluating the conditions and practices that are hazardous [21]. In 1998 Jannadi and Assaf [22] followed a checklist of necessary safety precautions in Saudi Arabian construction sites. The perceptions of workers on self-evaluated safety awareness, safety managing activities, conformity, and involvement in safety actions were measured at process industrial units incorporating 1566 employees [23].

In 2003 Teoa and Ling [24], used a technique comprising of 15 stages including a senses to extend and examine safety management system audit tools being used to evaluate the efficiency of construction sector’s safety system. Also, safety management systems execution and progress have been discussed [25-31]. 40 construction workers were examined by a questionnaire in southern Spain to analyse the effect of health and safety investment on the costs of construction company [32]. Similar study was carried out by El-

Mashaleh et al., in 2010 [33] with slight modifications for Jordanian construction industry. Construction worksites were analyzed through proposed solutions by quantified risk estimation techniques to downgrade the possibility of producing fatal accidents due to the result of risk value [34]. Williams et al., in 2010 [35] proposed a virtual fencing technology that triggers warning alerts to prevent workers from standing in hazardous positions.

It was estimated that 25 -33% of causalities in construction activities were due to crane accidents [36]. Operation of crane decided the lifting work nature. Suitable maintenance of work environment to meet the physiological and psychological demands of human prevented the accidents [37]. In fundamental tools, diagram analysis and risk rating and filtering were used. In advanced tools fault tree analysis (FTA), hazard and operability evaluation (HAZOP), hazard analysis and critical control points (HACCP), failure mode effective analysis (FMEA) were used and installed a severity categorization desk which categorizes the severity of outcome into sizeable, critical, critical, very serious and catastrophic [38]. In 2017, Vishwas and Gidwani [39] found that risk control in the construction activity was a complete and efficient way for identification, analysis and response of risks in Metro rail project objectives. The research outcome emphasized that the above said construction company considerably vary from the other construction companies in India in the implementation of risk management practices. They also found that the risk could be effectively managed only if the contractor understood the conditions and preferences of risk, their responsibilities and capabilities for management. The objective of this work is to identify and analyze hazards, the event sequences leading to hazards and the risks associated with hazardous events during material handling by dumper, material hoist/tower cranes, winches, mobile cranes and manual handling. Various techniques ranging from the basic qualitative techniques to the sophisticated quantitative techniques are existing for identify and analyze hazards. Multiple hazard analysis techniques are recommended because each has its own purpose, strengths, and weaknesses.

II. MATERIALS AND METHODS

HIRA chart for the various activities during material handling were identified in the project sites and are tabulated in Table 1. They are Material handling by dumper, by material hoists/tower cranes/winches, mobile cranes and manual handling. During these activities the various hazards and their health impacts were also identified. During material handling by dumper hazards like fall of person / dumper, Defective / poor condition of equipment / collision with personnel were identified, the health effects such as Fatal, Broken bones, Cut Wound, Finger Crush / Dislocation because of fall of persons/dumper were also notified. Applicable legal requirements were also notified.

The various parameters like probability, exposure, effect, RPN and significance were found for every activity and are formulated in Table 1.The different control measures adopted to overcome these hazard as shown in the table. After implementing the control measures the changes in these parameters were also given. Finally the various opportunities for effectively managing hazards were also found and they are tabulated. The same procedure was carried out for the other activities like material handling by material hoists/tower cranes/winches, mobile cranes and manual handling and they are shown in table 1.

Sl No	Activity	Hazard	Health Impacts	Applicable Legal Requirements	Evaluation of HIRA					Control Measures	After Implementing Control Measures					Opportunity
					ity	re	Effect	RPN	ance		ity	re	Effect	RPN	ance	
1	**MATERIAL HANDLING**															
a	By dumper	Fall of person / dumper	Fatal, Broken bones, Cut Wound, Finger Crush / Dislocation	Y	3	3	7	63	S	Deploy certified drivers and operators, deploy flagman to guide the movement of equipment, keep safe distance away from excavation edges, provide separate pedestrian access ways.	2	3	5	30	NS	Safe working operation of dumber
		Defective / poor condition of equipment / collision with personnel	Fatal, Broken bones, Dislocation	Y	3	4	10	120	S	Use inspected and certified equipments only, Ensure operator checks / inspection prior to use, carry out periodical inspections & regular maintainace, Follow specific instructions by the manufacturer for handling / operating the equipment.	2	4	4	32	NS	Safe working condition of equipment
b	By material hoist/tower crane/winches	Collapse of structure	Fatal, Broken bones, Cut Wound, Finger Crush / Dislocation	Y	3	4	7	84	S	Use inspected and certified equipment, tools & tackles only, deploy competent operators, carry out periodical inspections & regular maintainace, Avoid unathorized person to the vicinity	2	4	4	32	NS	

		Collision with near by structure or personnel	Fatal, Broken bones, Cut Wound, Finger Crush / Dislocation	Y	3	4	7	84	S	Prioritise the activity to control SIMOPS, Deploy certified operators, deploy trained signal man to guide the movement of equipment, keep safe distance away from moving/ swinging equipments. Barricade the swing area. Avoid unauthorized entry & display safety signages.	2	3	5	30	NS	Avoid collision for safe operation
		Wrong signaling/fall of person	Fatal, Broken bones, Cut Wound, Finger Crush / Dislocation	Y	3	4	7	84	S	Deploy trained signal man, ensure safe & inspected working platform, provide fall protection equipments such as safety nets and full body safety control etc.	2	4	3	24	NS	
		Failure of wire ropes	Fatal, Broken bones, Cut Wound, Finger Crush / Dislocation	Y	3	4	10	120	S	Use inspected and certified equipment, tools & tackles only, Ensure operator checks / inspection prior to use. Isolate the lifitng area. Carry out periodical inspections and regular maintenance.	2	2	6	24	NS	
		Misuse / Incorrect Operation	Fatal, Broken bones, crush, Dislocation	Y	3	4	7	84	S	Ensure availability of competent personnel for equipment operation. Operator shall be trained & authorised – possessing relevant operating permit. Do not leave the equipment with engine running condition. Do not attempt to stop the equipment	2	4	4	32	NS	Safe operation by competent person

										manually by pushing or pulling to restrict its movement from any direction.						
		Defective / poor condition of equipment/collision with personnel	Fatal, Broken bones, Dislocation	Y	3	4	10	120	S	Use inspected and certified equipments only, Ensure operator checks / inspection prior to use, carry out periodical inspections & regular maintainace, Follow specific instructions by the manufacturer for handling / operating the equipment.	2	4	4	32	NS	Safe working condition of equipment
		Poor communication /eye contact in between operator & signalman/Blind spot	Fatal, Broken bones, crush, Dislocation	N	3	4	5	60	S	Provide walky/talky for better communication, Deploy competent operator & signal man. Ensure close supervion	2	4	4	32	NS	
		Overloading the equipment / load imbalance.	Fatal, Broken bones, crush, Dislocation	Y	3	4	7	84	S	Do not overload any equipment & operate only within the rated capacity, Deploy only trained & authorised operator & crew members for loading materials, Ensure close Supervision	2	3	5	30	NS	Safe working operation of Equipment
c	Mobile Crane	Failure of lifting tackle & rope	Broken bones, Cut Wound, Finger Crush /	N	2	4	10	80	S	Use inspected and certified lifting tools and tackles only, Isolate the lifting area to avoid un authorised entry, Ensure periodical inspection with colour code system and regular maintenance	2	3	5	30	NS	

			Dislocation													
		Fall of person/ material	Fatal, Broken bones, Cut Wound, Finger Crush / Dislocation	Y	3	4	7	84	S	Remove loose materials & secure the load by using certified tools & tackles, Deploy competent operator & signal man. Ensure centre of gravity prior to lift load, Avoid unauthorized entry to the vicinity, Provide fall protection equipments such as hand rails, safety nets full body safety control while working at elevated positions. Do not stand/walk under suspended load.	2	4	4	32	NS	
		Failure of equipment parts including limit switches	Cut Wound, Abrasion,fracture, Finger Crush	N	3	3	4	36	S	Use inspected & certified equipment and carry out preventive maintenance and scheduled inspections. Ensure periodical inspection with colour code system	2	3	4	24	NS	
		Collision with moving object	Cut Wound, Abrasion,fracture, Finger Crush	N	3	4	5	60	S	Deploy certified operators, deploy trained signal man to guide the movement of equipment. Keep safe distance away from moving/ swinging equipments. Use walky talky for communication where necessary. Provide tag line to control the movement of load. Isolate the area to avoid unauthorized entry of people/vehicle. Do not stand/walk under the suspended load. Ensure close supervision	2	4	4	32	NS	

		Overloading the equipment / load imbalance.	Fatal, Broken bones, crush, Dislocation	Y	3	4	7	84	S	Do not overload any equipment & operate only within the rated capacity, Deploy only trained & authorised operator & crew members for loading materials, Ensure close Supervision	2	4	5	40	S	
		Crane overtune by unstable ground or base	Fatal, Broken bones, Dislocations	N	2	4	7	56	S	Position the equipment in the levelled/compacted surface only, provide adequate wooden pads to outrigger, Ensure to extend outrigger fully. Ensure close supervision. Deploy competent operator and trained signal man, Isolate the area to avoid unauthorized entry.	2	3	5	30	NS	
		Adverse Weather	Fatal, Broken bones, crush, Dislocation	N	2	2	7	28	NS	Stop the work during bad weather, Use safety googles, dust mask during heavy dust/wind. Inspect all electrical appliances and tools prior to start work after raining. Be alert of slip/trip/falls. Do not stand/ walk under any equipments or heavy structures.	2	2	4	16	NS	
	Manual Handling	Fall of material /person	Cut Wound, Abrasion,fracture, Finger Crush	N	3	4	4	48	S	Deploy sufficient and trained persons, Ensure the grip & secure the load before carry, follow safe techniques of manual handling including body posture & knee bend method, keep access/egress free from obstruction and slippery surface. Provide cover or pading on sharp object. Wear suitable hand gloves while handling sharp object or slippery loads.	2	4	3	24	NS	
		Coming in contact	Cardiac arest ,Musc	N	2	4	7	56	S	Be alert of live electrical cables to keep safe distance. Isolate the source of energy	2	4	4	32	NS	

		with electrical cable	le Cramps							where required. Wear rubber hand gloves while handling any electrical equipments/materials						
		Trip/slip/fall	Skin Burn, Cut Wound, Abrasion,fracture, Finger Crush	N	3	4	4	48	S	Keep access/egress free from obstruction/slippery and maintain regular housekeeping. Obtain assist to carry/move load.	2	4	3	24	NS	Easy walk through safe access
		Carry heavy/over load	Back Injury, Hernia, Finger Crush, Fracture	Y	3	3	5	45	S	Deploy sufficient/capable persons to carry load. Use mehanical lifting/handling equipment. Consider the health capasity of person before carry load. Deploy trained persons. Ensure close supervision.	2	3	4	24	NS	Distributing load by deploying sufficient persons

Table 1 HIRA chart for material handling in construction

III. RESULTS AND DISCUSSIONS

Risk created by various hazards during the different activities of material handling were evalauated by the formula

Risk = Probability X Exposure X Consequence

5 points X 5 points X10 points

For assessing the risks, different parameters like probability, exposure and consequence were considered in different scale ranges via probability in 5 point scale in different categories (i.e) 5 –may well be expected,4 – quite possible, 3-unusual but possible, 2- only remotely possible and 1- practically impossible as indicated in table 2. Similarly table 3 indicates scoring for exposure, in which 5 indicates continuous exposure, 4 indicates frequent (daily) exposure, 3 indicates unusual (monthly) exposure, 2 indicates occasional (yearly) exposure and 1 indicates exposure more than a year.

Scoring for effectiveness was given in 10 point scale, where 10 indicates any fatality, 7 indicates significance chance of fatality, 5 indicates serious injury, 4 indicates small chance of serious injury, 3 indicates major reportable, 2 indicates one reportable injury and 1 indicates minor injuries as shown in the table 4. Finally the level of risk was calculated by multiplying the values of probability, exposure and effectiveness. From the scoring the level of risk was assigned based on table 5. From this table the level of risks varied as very low (<10 %), low (11-20%), Moderate (21-30%), High (31-40%), Very high (41-50%) and extreme (> 50 %).

Based on the risk level the risk matrix was drawn as shown in figure 1 by assigning the different colors such as green color for very low risk, pale green for low level risk, yellow color for moderate level of risk, orange color for high level of risk, brown color for very high level of risk and red color for extreme level of risk.

From the risk matrix it is found that extreme condition risk level (i.e Values > 50%) was not present during material handling, but the very high risk levels (i.e values between 41-50%) were present in the hazards namely the defective/poor condition of equipment/collision with personnel during the activity of material handling by dumper. similarly hazards produced such as wire rope defects, defective /poor condition of equipment /collision with personnel during the activity of material handling by material hoist/tower crane/winches also having the risk levels in the very high level. For all these hazards after implementing the suitable control measures the values reduced to low level of risk for the defective/poor condition of equipment/collision with personnel hazards and defective /poor condition of equipment /collision with personnel, but for failure of wire rope the control measures worked promptly leading to very low risk level. Out of 21 hazards identified 7 hazards such as collapses of structure, collision with nearby structure or personnel, wrong signaling/fall of persons, misuse/incorrect operation during the activity of material handling by material hoist/tower crane/winches as well as fall of person/material, overloading the equipment/load imbalance mobile cranes and failure of lifting tackle & rope were fall in the range of high risk level. For all these hazards the control measures acted promptly for reducing the risk to low level except wrong signaling/fall of person to very low level (i.e < 10 %).

Five hazards namely fall of person/ dumper during material handling by dumper, poor communication/eye contact in between operator & signalism/blind, spot collision with moving objects and crane over tune by unstable ground or base during material handling by material hoist/tower crane/winches as well as coming in contact with electrical cable during the material handling by manually were fall within the moderate risk level, by implementing the various control measure mentioned in HIRA table the risk levels were reduced to low category.

Probability	Score
May well be expected	5
Quite possible	4
Unusual but possible	3
Only remotely possible	2
Practically impossible	1

Table 2

Exposure	Score
Continuous	5
Frequent (daily)	4
Unusual (monthly)	3
Occasional (yearly)	2
More than a year	1

Table 3

Effect	Score
Any fatality	10
Significant chance of fatality	7
Serious injury	5
Small chance of serious injury	4
Major reportable: Many persons getting reportable injury	3
One reportable injury (one person)	2
Minor injuries	1

Table 4

Level of Risk	Description
< 10	Very Low
11 - 20	Low
21 - 30	Moderate
31 - 40	High
41 - 50	Very High
>50	Extreme

Table 5

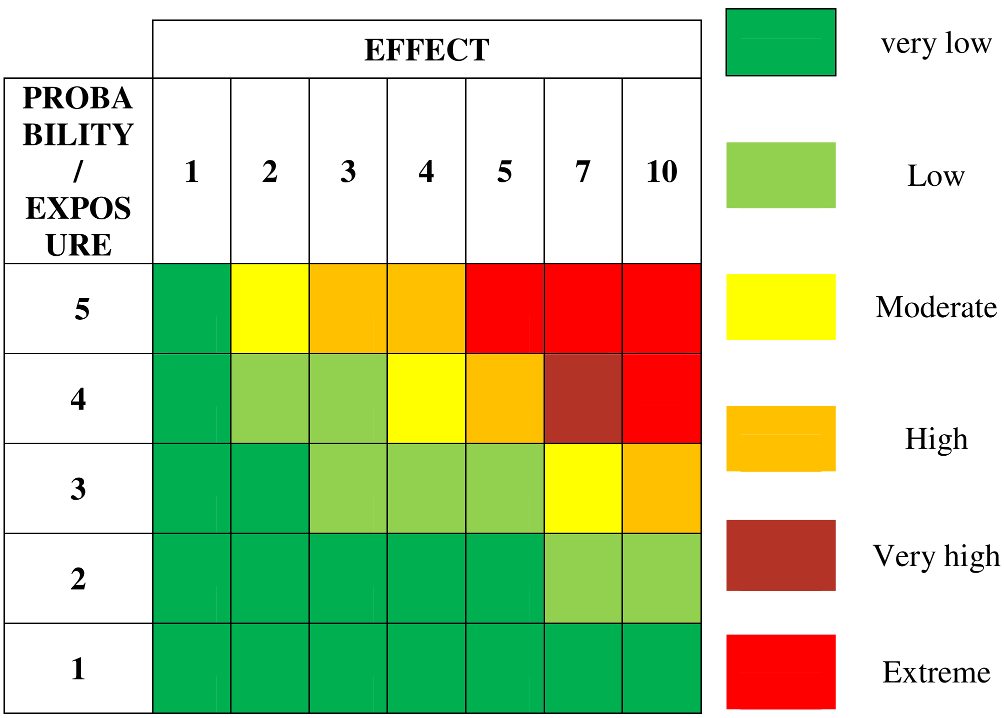

Figure 1 Risk matrix for material handling & color codings.

Five hazards namely failure of equipment parts including limit switches and adverse weather during the activity of material handling by material hoist/tower crane/winches as well as fall of material/person, trip/slip/fall and carry heavy/over load during the activity of manual material handling were fall in the range of low risk levels, by incorporating the suitable control measures these risk level were reduced to very low risk levels.

IV. CONCLUSION

Materials handling during construction activities are important to improve cumulative result of construction sectors in terms of time, budget (cost), quality and productivity. This study revealed that dangerous situations in the material handling can be effectively identified, assessed and controlled by **HIRA** (Hazard identification and risk assessment). It was also informed that systematic techniques used by effective checklist and health and safety regulations to assess risks. Toolbox meetings, site meetings, posters and informal verbal communication should be used to communicate risk. Regular inspections, penalties and compliance certificates issued by regulatory institutions influence risk management more. This study also provides factors hindering health and safety risk management in material handling during construction, which includes the low level of public awareness of regulations, lack of resources such as personnel and funds, coverage of the regulations, complexity of design, the procurement system and the low level of education, site configuration, and location.

V.FUTURE SCOPE

The authors believe that the results achieved are most useful for the hazard identification and risk assessment in construction, and other departments. The results could be used not only for the HIRA system proposed, but also to trigger questions and ideas for other issues of concern within the construction field.

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