An Analytical investigation on Improving Safety Performance in Construction Sites

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Abstract - Construction industries are known to be hazardous due to complex tasks, change of work location, climatic conditions and temporary organizational management. The consequences of these hazards may involve occupational diseases, injuries and fatality. Injuries and accident rates are high in a construction site when compared with other manufacturing industries. Safety is one of the key factors in construction sites to mitigate the severity of the risk. Assessing the performance of the site concerning safety is an important part of the management system as it provides information on the safety of the worker as well as the task. Hence the aim of this research is to investigate the site safety performance and propose a methodology for enhancement. This is done in basically four parts viz., quantification of risk involved in each task, accounting for unsafe supervision, selection of right worker for the right task and usage of PPEs. Safety performance cannot be measured only with the accidents/injuries in the site but the factors which influence the unplanned events have to be highlighted while determining the performance rate. The factors include the task/conditions of the site. Risk involved in each task is quantified using Hazard Identification and Risk Assessment (HIRA) technique. The hazards in the sites are identified through direct observation and previous safety reports and the risk values are determined using likelihood and severity ratings of each hazard.

Keywords - Construction Safety ,PPE, Hazard Identification and Risk Assessment (HIRA)

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INTRODUCTION

Safety refers to the absence of accidents. Stated differently, safely refers to the protection of workers form the danger of accidents. Safety, in simple terms, means freedom from the occurrence or risk of injury or loss. Industrial safety or employee safety refers to the protection of workers from the danger of industrial accidents. An accident, then is an unplanned and uncontrolled event in which an action or reaction of an object, a substance, a person, or a radiation results in personal injury. Accidents are of different types. They may be classified as major and minor ones, depending upon the seventy of the injury.

Construction sites are dangerous places where injury or death or illness can cause to workers. These can happen due to electrocution, falling from height, injuries from tools, equipment and machines; being hit by moving construction vehicles, injuries from manual handling operations, illness due to hazardous substance such as dust, chemicals, .etc. Even a nail standing up from a discarded piece of wood can cause serious injury if trodden on in unsuitable shoes.

Statistics of accidents in the construction industry in India are scarce. The rate of accidents on construction industry is very high not only in India but also in many other countries including the developed. Statistics of UK, USA and some other countries indicate that the industry has a very high hazard potential and high incidence of fatal accidents. For example, the average yearly rate of accidents for 1000 worker in the construction industry in UK is approximately 4 times the corresponding average rate of all manufacturing industries. This article will focus on various aspects of safety in construction sites. However, it does not deal with the aspects relating to the use of personal protective equipment in construction sites, which will be dealt in a separate article.

OBJECTIVES

- To study the different safety norms and regulation for building and infrastructure projects .
- To study the causes of unexpected circumstance on construction site by taking suitable case study
- To identify the hazards in the construction site and to quantify the risk involved in each task using HIRA technique
- To analysis the effect of these circumstance

on planning and scheduling of construction projects and gives remedial measures to avoid these mishaps

DATA COLLECTION

The risk is quantified for every task in the construction site using Hazard Identification and Risk Assessment (HIRA) technique. As HIRA is a generic method for quantifying risk in all types of workplaces, this method is adopted to classify and prioritize the risk zone. The purpose of risk assessment is to identify all the factors that may cause harm to employees and others (the hazards) and consider what are the chances that harm and the possible severity that could come from it (the risks) . The person who is performing risk assessment should be familiar with all the tasks in the construction site, must have in-depth knowledge of the likelihood and severity of the hazards The risk involved in the construction site is quantified through HIRA technique. This study proposed an improved methodology for risk assessment where the hazards in the task and the consequence to the workers are integrated. Risk zones are categorized and the percentage of risk in each category is determined. The proposed methodology helps the builders/owners to look into unsafe conditions which further seeds to the improvement of the safety performance of the site.

The data collection method involves a questionnaire survey, face-to-face interviews, referring field book and experts' opinion. The respondents are workers, supervisors, site engineers, safety officers and project managers. The various types of questionnaire survey which is adopted in this study and it will analysis HIRA Techniques

Hazard Identification

Hazard identification is a process of determining whether any condition or an event has the potential to cause damage both to the workers and the site. In order to identify the hazards in the construction site checklist method, workplace inspection method, job safety analysis and accident investigation method can be used. Hazards are classified as physical (i.e., manual handling, ergonomics and fire), chemical (i.e., flammables), mechanical (i.e., types of machinery) and electrical. In this study, hazards are identified using workplace inspection in which observation is done through site visits and a discussion is done with the safety engineers and supervisors for better understanding of hazards in the site.

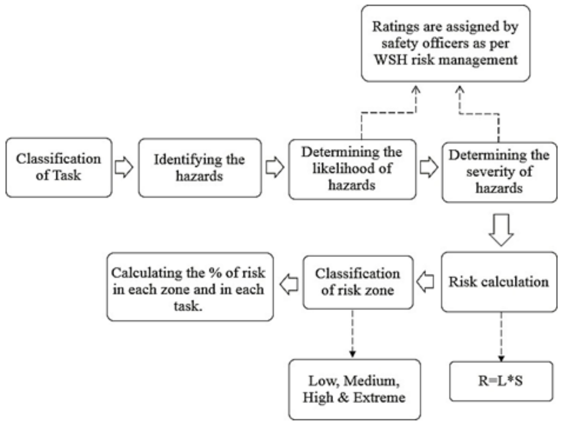
Table 1.1 Risk matrix with descriptive ratings

Likelihood / Severity	Rare (1)	Remote (2)	Occasional (3)	Frequent (4)	Almost Certain (5)
Catastrophic (5)	L	M	H	E	E
Major (4)	L	M	M	H	E
Moderate (3)	L	M	M	M	H
Minor (2)	L	L	M	M	M
Negligible (1)	L	L	L	L	L

whereas: L – Low, M – Medium, H – High, E – Extreme

Table 1.2 Risk response

S. No	Risk Score	Risk Category	Risk Response
1.	20-25	E	Activity should be modified
2.	11-19	H	Work not to proceed until further mitigationmeasures were implemented
3.	6-10	M	Requires review and approval to perform thisactivity
4.	1-5	L	Can be performed using existing standard controls and plans



STUDY AREA

In this study, a building construction site in the Pune city will be chosen which follows all the rules and regulations as per the Indian standard safety code of practice. The managerial team consists of a Project Manager, Planning Engineer, Site Engineer, Safety Engineer, Safety Supervisor and Site supervisor. There is a separate department for environmental health and safety where all the contractors are asked to update their safety documents periodically. A training center is established in the site where accident-causing visuals are displayed and sufficient training is given to the workers. . After constructing each questionnaire, a discussion is made with the safety engineers/supervisors to ensure the sufficiency of the addressed factors.

Questionnaire to determine safety performance

TASK	QUESTIONS
T1	1. Is the excavated soil kept away from the excavation?
	2. Will you ensure that there are no underground services before excavation?
	3. Do you use safety helmets and footwear during excavation?
	4. Does the supervisor inspect the excavating area?
T2	1. Is there any gangways or fixed platform to carry the steel bars?
	2. Do you carry steel bundles on your shoulders?
	3. Do you wear hand gloves when you carry steel bars?
T3	1. Is there any safety signs and barricades to keep the unauthorized person away from the spot?
	2. Is there any experienced form watcher during the work?
	3. Does the management provides adequate illumination for the work?
T4	1. Whether the chains and rollers of the concrete mixers are adequately guarded?
	2. Are the electric wires checked before starting the cement mixer?
	3. Do you use hand gloves and footwear while working with cement mixer?
T5	1. Does the bar bending take place in a separate shed?
	2. Do you use hand gloves while bending steel bars?
	3. Do you get frequent breaks while doing this work
T6	1. Do you ensure whether there are combustible materials, suitable blanketing & fire extinguishers in the workplace?
	2. Do you wear suitable cover all and goggles before the start of work?
	3. Are the cylinders in the hot work marked as empty or full?
	4. Do you light the welding torches with special lighters?
T7	1. Do you wear suitable PPE during pouring of concreting?
	2. Are the grouting equipment securely fenced?
	3. Are the movement of the concrete buckets governed by signals?
T8	1. Do you stack the materials (bricks, coarse & fine aggregates, cement bags) properly?
	2. Do you wear proper gloves and footwear while handling bricks & coarse aggregates?
	3. Do you lift heavy steel bars using slings and tackles?
	4. Do you wear protective clothing, respirators and goggles while handling cement bags and
T9	1. Are the floors are well maintained and chips or other loose materials kept free?
	2. Are push sticks provided while using a saw?
	3. Are all the saws guarded?
	4. Are the person working competent?
T10	1. Are all the earth moving equipment and vehicles inspected at least once a week?
	2. Are the trucks fitted with an automatic load indicator?
	3. Are any safe gangways provided for the workers in loadingand unloading?
	4. Is a signaller used during the vehicle movement?
T11	1. Does the mobile crane have suitable horns, head lights, side lamps & flashing directional indicators?
	2. Are tag lines used to control the load in handling structural steel?
	3. Are the cranes well maintained?
T12	1. Are the hoist ways protected by a substantial enclosure?
	2. Are all the hoist platforms fitted with guards and gates?
	3. Is the hoist operator adequately trained and competent?
	4. Is there any inspection for the hoist once a week?
T13	1.Do you use hand gloves and a mask while drilling?
	2. Do you check the electrical wires before the start of work?
	3. Are the drilling equipment inspected once a week?
T14	1. Do you check for uninsulated electric wire exists within 3 m of the working platform?
	2. Will you ensure that there are no scrap materials in the working platform?
	3. Do you check whether the scaffold is provided with a warning lights?
	4. Will you ensure that there is a screen or canopy provided above the scaffold for avoiding falling objects from height?
T15	1. Do you receive 1 litre of milk per day while handling lead-based paints?
	2. Are the paint scrapings removed daily from the premises and destroyed by burning at a safe place?
	3. Do you use protective clothing and respiratory equipment whilepainting?

Determination of likelihood ratings

The likelihood is defined as the frequency of occurrence of a particular hazard and is used in quantifying the risk for each task in the construction site. Likelihood ratings are used in risk assessment studies to know "how likely the identified hazard can occur?" These ratings may differ based on the site safety conditions and mitigations measures that are adopted inthe site. The respondents for this survey are only safety engineers/supervisors and the level of agreement is obtained as mentioned in Table

Table 1.2 Likelihood ratings

Questionnaire survey to determine the likelihood of the hazards		
Name		
Organization		
Designation		
Age		
Follow the ratings and descriptions as given below		
Level	Likelihood	Description
1	Rare	Not likely to happen but still possible
2	Remote	Not expected to happen under normal circumstances
3	Occasional	Possible to occur
4	Frequent	Common occurrence
5	Almost Certain	Repeating occurrence

Hazards	Ratings				
Underground utilities	a) 1	b) 2	c) 3	d) 4	e) 5
Soil collapse	a) 1	b) 2	c) 3	d) 4	e) 5
Ground water seepage	a) 1	b) 2	c) 3	d) 4	e) 5
Slips and trips	a) 1	b) 2	c) 3	d) 4	e) 5
Poor access	a) 1	b) 2	c) 3	d) 4	e) 5
Fall from height	a) 1	b) 2	c) 3	d) 4	e) 5
Struck by object	a) 1	b) 2	c) 3	d) 4	e) 5
Entanglement	a) 1	b) 2	c) 3	d) 4	e) 5
Noise	a) 1	b) 2	c) 3	d) 4	e) 5
Improper work posture	a) 1	b) 2	c) 3	d) 4	e) 5
Unskilled operation	a) 1	b) 2	c) 3	d) 4	e) 5
Stack collapse	a) 1	b) 2	c) 3	d) 4	e) 5
Overhead power lines	a) 1	b) 2	c) 3	d) 4	e) 5
Poor maintenance	a) 1	b) 2	c) 3	d) 4	e) 5
Inhalation of dust	a) 1	b) 2	c) 3	d) 4	e) 5
Fall of objects	a) 1	b) 2	c) 3	d) 4	e) 5
Vibration	a) 1	b) 2	c) 3	d) 4	e) 5

Determination of Severity Rate

The severity rate is defined as the impact of the hazard on people and the environment. For each hazard mentioned in the risk assessment sheet, the safety experts are asked to give the severity rate as per the description mentioned in Table 4.4.These ratings are used in three different forms of the study viz., to perform risk assessment, to determine safety performance and to quantify the risk involved in non-usage of PPE. The severity scale is adopted from the code of practice on workplace safety & health as mentioned. For each study, the severity rate is obtained through the safety engineer who is responsible for the particular work.

Table 1.3 Severity ratings

Questionnaire survey to determine the severity of the hazards		
Name		
Organization		
Designation		
Age		
Follow the ratings and descriptions as given below		
Level	Severity	Description
5	Catastrophic	Fatality, fatal diseases or multiple major injuries.
4	Major	Amputations, major fractures, multiple injuries, occupational cancer, acute poisoning.
3	Moderate	Includes lacerations, burns, sprains, minor fractures,dermatitis, deafness, and work-related upper limb disorders.
2	Minor	Includes minor cuts and bruises, irritation, ill-health with temporary discomfort.
1	Negligible	Not likely to cause injury or ill-health

Hazards	Ratings				
Underground utilities	a) 1	b) 2	c) 3	d) 4	e) 5
Soil collapse	a) 1	b) 2	c) 3	d) 4	e) 5
Ground water seepage	a) 1	b) 2	c) 3	d) 4	e) 5
Slips and trips	a) 1	b) 2	c) 3	d) 4	e) 5
Poor access	a) 1	b) 2	c) 3	d) 4	e) 5
Fall from height	a) 1	b) 2	c) 3	d) 4	e) 5
Struck by object	a) 1	b) 2	c) 3	d) 4	e) 5
Entanglement	a) 1	b) 2	c) 3	d) 4	e) 5
Noise	a) 1	b) 2	c) 3	d) 4	e) 5
Improper work posture	a) 1	b) 2	c) 3	d) 4	e) 5
Unskilled operation	a) 1	b) 2	c) 3	d) 4	e) 5
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Poor maintenance	a) 1	b) 2	c) 3	d) 4	e) 5
Inhalation of dust	a) 1	b) 2	c) 3	d) 4	e) 5
Fall of objects	a) 1	b) 2	c) 3	d) 4	e) 5
Vibration	a) 1	b) 2	c) 3	d) 4	e) 5

Determination of Workers Performance

For this study, the respondents are the workers from whom the information on basic traits/characteristics namely age, experience, education, competency, accident and safety knowledge are collected. A total of 100 responses are received with satisfaction. The competency level and safety knowledge level are collected from the field data book. A sample questionnaire to collect the workers' basic traits is mentioned in Table 4.5.

Table 1.6 Factors considered for workers performance

Questionnaire survey to identify the workers' basic traits			
Organization			
Name of the employee			
Age	a) <25	b) 25-50	c) >50
Education	a) Primary	b) Middle	c) Higher secondary
Experience	a) <7	b) 7-15	c) >15
Type of accident	a) Near miss	b) First aid	c) Lost time injury

Safety Performance of the Site

A questionnaire survey is conducted with 45 workers to determine the safety performance of the site. The first part of the questionnaire consists of basic details of the workers such as name, age and experience whereas the second part consists of factors pertaining to site safety performance such as toolbox talk, safety supervision, safety training, availability and use of PPEs as mentioned in Table 4.7. Other factors such as the type of accidents that occurred in the particular site and the competency of the worker have been extracted from the site data book.

Table 1.7 Factors to determine site safety performance

Questionnaire survey to determine safety performance of the site		
Name		
Age		
Experience		
Tick the frequency of the factors mentioned below		
Q. No	Factors	Frequency
1.	Tool box talk	a) Rare
		b) Occasional
		c) Every time before starting the task
2.	Safety supervision	a) Rare
		b) Occasional
		c) Almost certain
3.	Safety training	a) Rare
		b) Occasional
		c) Almost certain
4.	PPE – availability	a) No additional PPE
		b) 50% is additional
		c) More than enough
5.	PPE – usage	a) Only helmets
		b) Both helmets & footwears
		c) Use all required PPEs

Non-Usage of Personal Protective Equipments

The main objective of this questionnaire survey is to quantify the risk of workers by non-usage of PPE in the site. Two safety engineers in the particular site were consulted to acquire necessary details such as a list of PPEs needed for each task as shown in Table 4.8 and severity values if PPE is not used. For this construction site, the use of safety helmets and foot wears are the mandatory PPEs for all the workers, supervisors, engineers and visitors in the site. The most common PPEs which is used in the construction site are Safety Helmets (SHe), Hand Gloves (HG), Safety Mask (SM), Goggles (Go), Ear Plugs (EP), Safety Shoes (SS), Coverall (Co), Apron (Ap) and Safety Harness (SHa)

Table 1.5 List of PPE required for each task

Task	SHe	HG	SM	Go	EP	SS	Co	Ap	SHa
T1	=	=	=	=	=	=	=	x	x
T2	=	=	x	=	=	=	=	x	x
T3	=	=	x	=	x	=	=	x	x
T4	=	=	=	=	=	=	=	x	x
T5	=	=	x	=	=	=	=	x	x
T6	=	=	=	=	x	=	x	=	x
T7	=	=	=	=	=	=	=	x	x
T8	=	=	x	=	x	=	=	x	x
T9	=	=	=	=	=	=	=	x	x
T10	=	=	=	=	=	=	=	x	x
T11	=	=	=	=	=	=	=	x	x
T12	=	=	=	=	=	=	=	x	x
T13	=	=	=	=	=	=	=	x	x
T14	=	=	=	=	=	=	=	x	=
T15	=	=	=	=	=	=	=	x	x

The first part of the questionnaire consists of basic details such as name, age and experience whereas the second part consists of a list of taskswith their associated PPE as mentioned in . A five-point Likert scale is adopted (5-strongly disagree to 1 strongly agree) to determine the level of agreement. For example, if the worker doesn't use safety helmets during excavation their level of the agreement will be "strongly disagree". When this is compared with the likelihood scale it will be equivalentto the rating "rare". Then the risk is quantified by multiplying the severity and likelihood values.

Table 1.6 Usage of PPE

Questionnaire survey to identify the usage of PPE						
Name						
Age						
Experience						
How likely are the PPEs are used in construction tasks?						
Notation	Usage of PPE	Level of Agreement				
		SA	A	NAD	D	SD
T1	1. Safety helmets					
	2. Hand gloves					
	3. Safety mask					
	4. Goggles					
	5. Ear plugs					
	6. Safety shoe					
	7. Coverall					
T2	1. Safety helmets					
	2. Hand gloves					
	3. Goggles					
	4. Ear plugs					
	5. Safety shoe					
	6. Coverall					
T3	1. Safety helmets					
	2. Hand gloves					
	3. Goggles					
	4. Safety shoe					
	5. Coverall					
T4	1. Safety helmets					
	2. Hand gloves					
	3. Safety mask					
	4. Goggles					
	5. Ear plugs					
	6. Safety shoe					
	7. Coverall					
T5	1. Safety helmets					
	2. Hand gloves					
	3. Goggles					
	4. Ear plugs					
	5. Safety shoe					
	6. Coverall					
T6	1. Safety helmets					
	2. Hand gloves					
	3. Safety mask					
	4. Goggles					
	5. Safety shoe					
	6. Apron					
T7	1. Safety helmets					
	2. Hand gloves					
	3. Safety mask					
	4. Goggles					
	5. Ear plugs					
	6. Safety shoe					
	7. Coverall					
T8	1. Safety helmets					
	2. Hand gloves					
	3. Goggles					
	4. Safety shoe					
	5. Coverall					
T9	1. Safety helmets					
	2. Hand gloves					
	3. Safety mask					
	4. Goggles					
	5. Ear plugs					
	6. Safety shoe					
	7. Coverall					
T10	1. Safety helmets					
	2. Hand gloves					
	3. Safety mask					
	4. Goggles					
	5. Ear plugs					
	6. Safety shoe					
	7. Coverall					

T11	1. Safety helmets					
	2. Hand gloves					
	3. Safety mask					
	4. Goggles					
	5. Ear plugs					
	6. Safety shoe					
	7. Coverall					
T12	1. Safety helmets					
	2. Hand gloves					
	3. Safety mask					
	4. Goggles					
	5. Ear plugs					
	6. Safety shoe					
	7. Coverall					

T13	1. Safety helmets					
	2. Hand gloves					
	3. Safety mask					
	4. Goggles					
	5. Ear plugs					
	6. Safety shoe					
	7. Coverall					
T14	1. Safety helmets					
	2. Hand gloves					
	3. Safety mask					
	4. Goggles					
	5. Ear plugs					
	6. Safety shoe					
	7. Coverall					

	8. Safety Harness					
T15	1. Safety helmets					
	2. Hand gloves					
	3. Safety mask					
	4. Goggles					
	5. Ear plugs					
	6. Safety shoe					
	7. Coverall					

DATA ANALYSIS

The risk is quantified for every task in the construction site using Hazard Identification and Risk Assessment (HIRA) technique. As HIRA is a generic method for quantifying risk in all types of workplaces, this method is adopted to classify and prioritize the risk zone. The purpose of risk assessment is to identify all the factors that may cause harm to employees and others (the hazards) and consider what are the chances that harm and the possible severity that could come from it (the risks) . The person who is performing risk assessment should be familiar with all the tasks in the construction site, must have in-depth knowledge of the likelihood and severity of the hazards

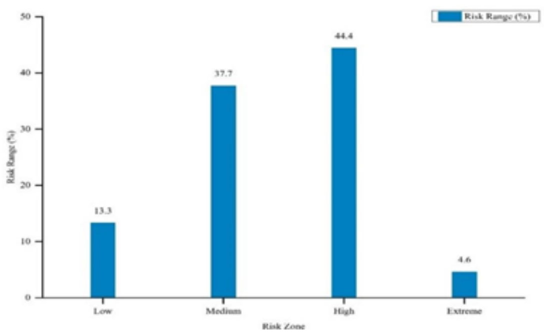
Relative Percentage Of Risk In Each Zone

The risk in the construction site is assessed through HIRA and the risk zones are classified accordingly. The relative percentage of risk involved in the construction site with respect to the risk zone is calculated using Equation (1).

$$\% \text{ of risk in each zone} = \frac{No.of\ hazards\ in\ each\ zone}{Overall\ no.of\ hazards}$$

Therefore, to calculate the relative percentage of risk in each zone, the number of hazards in each zone and the number of hazards in the site must be known. In this particular construction site the percentage of high risk is estimated to be 44.4 which is higher when compared to other risk zones as presented in Figure 4.2. It is also found that the relative risk for both the high and the extreme risk zone is 49% indicating almost half of the tasks are high- risk tasks. Hence determining the relative percentage of risk zone in construction sites will create awareness to the owners/builders to discover suitable mitigation measures to reduce the high and extreme risk zones to low as possible. Also, the allocation of workers in the extreme/high-risk zones must be allocated with their competency and skills to reduce the injury/accident rate in the site.

Figure 1 Relative percentage of risk in each zone



Relative Percentage Of Risk In Each Task

In order to determine the relative percentage of risk for each task, the risk value calculated from Table 4.3 is considered. The risk value for a particular task is calculated by dividing the sum of the risk value for all the hazards identified in the activity by the overall risk. It is given by Equation (2)

$$\% \text{ of risk in each task} = \frac{\sum H}{R} \times 100 \quad (2)$$

where H is the risk value of each hazard in the task and R is the overall risk.

After calculating the relative percentage of risk in each task it is ranked to know the high-risk construction task. From Figure 4.3 it can be known that crane operation, scaffolds/ladders and drilling are the tasks with a higher percentage of risk. Hence determining the relative percentage of risk in each task will create awareness among the safety officers to stop the particular task, implement suitable mitigation measures and then restart the task. By doing so the task will be safer, workers who are working might not be harmed and future accidents can be minimized. Furthermore, the safety engineers must give regular toolbox talk before the start of these tasks and the workers working in these tasks must use proper PPE to avoid the severity of the hazards.

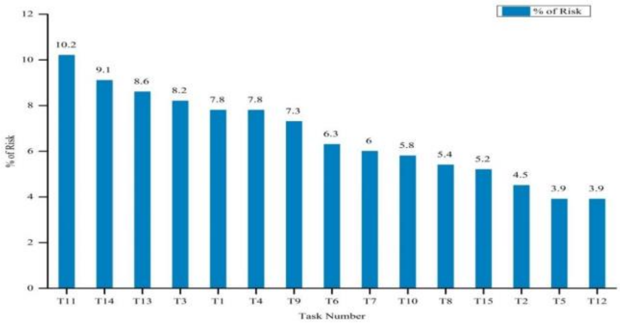


Figure 2 Relative percentage of risk in each task

CONCLUSION

1) Construction industry is considered as the back bone of the country. Its contribution in the development of the country is very crucial, since it is the second largest sector employing the workers next to the agricultural sector, but in case of accident it is the first sector next to the road accidents.

2) This does not result only in loss of life and property and slow down of the work, but also create a feeling of fearness amongst its operators (management, supervisors, workers, etc). Safety Management therefore plays a very important role in construction industry

3) HIRA techniques can be a best suitable for Investigation on improving performance on construction sites The maximum hazards involved in each and every task of the construction site are identified through direct observation.

4) Risk is quantified through the likelihood and severity values as pointed out by the safety expert. Risk classification is done according to the risk range and it is observed that 13.3 % of low risk, 37.7 % of medium risk, 44.4 % of high risk and 4.6% of extreme risk are present in the construction site.

5) The percentage of risk in each activity is calculated and it is ranked to know the high-risk activity. It is known that crane operation (10.4%), height work (9.1%) and drilling (8.6%) are the major high-risk activities.

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