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Risk Management and Response: A Comparative Study of Occupational Hazards on Construction Sites

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ABSTRACT: The Indian construction industry has scope of exponential growth in recent future. Time management, Risk management, site safety, quality work will play important role, if Indian construction industry has to compete with international standards. Whereas presently occupational hazards is matter of concern. The objective of this research is to make comparative study for identification of critical undesirable events occurring on construction sites, with the help of Risk Mitigation Techniques.

KEYWORDS: Construction Industry, India, Risk, Risk Management, Risk Mitigation Technique.

I. INTRODUCTION

The Indian construction industry is valued at over USD 126 Billion. USD 1 Trillion investments for infrastructure sector projected during 2012-17. Present levels of urban infrastructure are inadequate to meet the demands of the existing urban population. There is need for re-generation of urban areas in existing cities and the creation of new, inclusive cities to meet the demands of increasing population and migration from rural to urban areas. [1]

The construction industry is often considered as a risky business due to its complexity and strategic nature. It incurs a numerous project stakeholders, internal and external factors which will lead to enormous risks. (S. M. Renuka et al, 2014) [2]. Risk is an integral part of any activity. In early days, the risk was not considered that seriously as it should have been, because of which many consequences were required to be faced.

In this study 'The Proportional Risk Assessment (P.R.A.T.) Technique' [3] and 'Risk Response Technique' [5] is used for identification of critical events. Whereas data is analyzed using proportional formula for calculating quantified risk due to hazard and Risk Assessment Tables. [5] The tables help to determine the action required to be taken based on category of impact of risk.

II. LITERATURE REVIEW

Alone et al [4] describe, there are four main ways in which risks can be mitigated. The four ways are as follows:a. Reduced or Eliminated, b. Transferred,
c. Avoided, d. Absorbed or pooled
Risk assessment tables are very useful in the risk mitigation strategy.

Chris Chapman and Stephen Ward (2003) [6], says the scope for uncertainty in any project is considerable, and most project management activities are concerned with managing uncertainty from the earliest stages of the Project Life Cycle (PLC), clarifying what can be done, deciding what is to be done, and ensuring that it gets done.

Kolhatkar& Dutta (2013) [7], observe that risks are the integral part of a construction project. But skilful handling of the risk is very important. For that identification of risk is very important. There are following types of risks- Financial Risk, Business Risk, Technology Risk, Political Risk and Project Risk. This paper includes overview on all possible risks occurring in a construction project, common sources of risk in a construction project and possible ways to mitigate the risks.

Marhavilas (2009) [3], emphasizes that the risk estimation is a very crucial part of the whole procedure of evaluating hazards in the work. The risk can be considered as a quantity, which can be measured and expressed by a mathematical relation, under the help of occupational accidents' data. This paper analyzes a quantified risk estimation technique (QRET).

$R = P \cdot S \cdot F$

Where, R: the Risk S: the Severity of Harm Index
P: the Probability Index F: the Frequency Index

Nguyen, Bhagavatulya, Jacobs (2014) [8], mention that the primary intent of their research study is to focus on the India construction transportation sector with an emphasis on multiple project risk factors. A data collection questionnaire was administered to Indian construction companies with a 66% response rate. Respondents were asked to rate among 30 identified industry risk factors. The study results indicated that several of the risks highlighted have a high impact even if the probability of occurrence is low. It is also understood that project management teams are not effective in terms of communication with project stakeholders, and are incapable of formulating the correct strategies when projects are not in good health. The research outcome suggests that the Indian construction transportation sector needs to employ innovative technologies and better contract management strategies to overcome project risk factors.

Considering the above aspects, this study focuses on the following objectives: -

i) Identification of the few critical events with respect to the various occupational hazards occurring on a residential construction site.
ii) Suggest a risk response action plan so as to decide a better way for risk mitigation out of four risk mitigation ways available.

III.RESEARCH METHODOLOGY

The research work initiated with study of few risk assessment techniques and the PRAT and Risk Response Technique were selected for this particular research. As per the requirements of the techniques, the unknowns of formulae and Probability of occurrence for each risk event was necessary for analysis. A questionnaire survey was prepared and given to many experts for the response on description of consequences of risk event occurrence. Data was collected from 55 various residential construction sites in Pune &Pimpri-Chinchwad area. The estimated cost of the projects ranges from 50 Cr to 150 Cr. Most of the projects were of 3 – 4 years of duration.

IV.QUANTITATIVE ASSESMENT OF RISK

The risk can be quantified and considered as a quantity, which can be measured and expressed by a mathematical relation, under the help of real accidents' data. The quantitative calculation of the risk (or quantified risk evaluation) can be given (Marhavilas&Koulouriotis) [3] [4] by the following relation:

$$R = P \cdot S \cdot F \quad \dots (4.1)$$

Where: R: the Risk S: the Severity of Harm Index
P: the Probability Index F: the Frequency Index

Each factor in equation (4.1), takes values in the scale of 1-10, so that the quantity R can be expressed in the scale of 1-1000. The Probability Index (P) can be calculated for various undesirable events by using the corresponding number of accidents and the following equation:

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$$P = \frac{Number\ of\ accidents\ or\ undesirable\ events}{Total\ number\ of\ accidents}\ x\ 10 \ldots\ldots (4.2)$$

The Severity of Harm Index (S) is estimated from the gradation scale of Table 4.1. The Frequency Index (F) shows the number of accidents during a definite time period. In order to calculate the accidents' frequency (per day), the data for a 1 year time period (i.e. with 48 working weeks and each working week with 5 working days) is used as:

$$Accident\ Frequency = \frac{Number\ of\ accidents\ per\ event}{48 \cdot 5} \ldots\ldots.. (4.3)$$

Then the Frequency Index (F) is calculated by the combination of equation's (4.3) result, and the gradation scales of Table 4.2.

Table 4.1: Gradation of the Severity of Harm Index in association with the undesirable event

Severity of Harm Index (S)	**Description of Undesirable Event**
10	Death
9	Permanent total inefficiency
8	Permanent serious inefficiency
7	Permanent slight inefficiency
6	Absence from the work >3 weeks, and return with health problems
5	Absence from the work >3 weeks, and return after full recovery
4	Absence from the work >3 days and <3 weeks, and return after full recovery
3	Almost Absence from the work <3 days, and return after full recovery
2	Slight injuring without absence from the work, and with full recovery
1	No one human injury

Source: Marhavilas (2009) [3]

Table 4.2describes the Frequency Index (F) which is used in interpolation between no. of accidents per year and Frequency index.

e.g. 44/48=0.91 accidents per working week, which corresponds to F= 3.64 (Interpolation between 3 and 4).

Table 4.2: Gradation of the Frequency Index in association with the undesirable event

Frequency Index (F)	**Description of Undesirable Event**
10	Permanent presence of damage
9	Presence of damage every 30 sec
8	Presence of damage every 1 min
7	Presence of damage every 30 min
6	Presence of damage every 1 hr
5	Presence of damage every 8 hr
4	Presence of damage every 1 week
3	Presence of damage every 1 month
2	Presence of damage every 1 year
1	Presence of damage every 5 years

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Source: Marhavilas (2009) [3]

Based on the outcome of Risk Value (R) (Equation 4.1) the table 4.3 gives urgency level for required action to be taken. e.g. R= 486.73, it lies in 400-600. So as per Table 4.3, action must be taken within 7 days.

Table 4.3: Gradation of the Risk Value in association with the urgency level of required actions

Risk Value (R)	**Urgency level of required actions**
600-800	Immediate action
400-600	Action during 7 days
200-400	Action during 1month
100-200	Action during 1 year
<100	Immediate action is not necessary but it is required the event surveillance

Source: Marhavilas (2009) [3]

V. RESULTS OF P.R.A.T.

The risk estimation is a very crucial part of the whole procedure of evaluating hazards in the work.

As per Table 5.1, where the number of accidents in the construction worksites is N_{CW} = 44 and the total number of accidents on the worksites is N_T=293, we have the result of P = (44/293) x10=14.53. The Frequency Index (F) has been calculated using equation (4.3) and the gradation scale of Table 4.2, so that 44/48=0.91 accidents per working week, which corresponds to F= 3.64 (according to Table 4.2 and in association with the use of linear interpolation for the intermediate values).

The outcome results of the risk estimation R of one year, according to the QRET technique (Table 5.1, column F) show that 4 critical events with respect to the 10 occupational hazards on the Construction Worksites are:

a) Mis-operation of machinery/equipment/tools (with R=296.51>200),
b) Contact with electric shock (with R=259.46>200),
c) Object slips on floor (with R=221.96>200),
d) Traffic accidents (with R=216.91>200)

As per the urgency levels of the required actions given in Table 4.3, it is clear that the necessary actions should be taken within a maximum period of one month.

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Table 5.1: Accident's statistical information of one year

(A)	(B)	(C)	(D)	(E)	(F)
Description of Undesirable Event	**Number of Accidents**	**Probability Index(P)**	**Severity of Harm Index (S)**	**Frequency Index(F)**	**Risk Value(R)**
Drops (Object/tool falls on person from height)	44	14.53	3	3.64	158.64
Collapse of temporary structure	22	7.43	3	3.28	73.14
Person falling from height	36	12.16	4	3.56	173.19
Object slips on floor (Impact on stable objects, hits by moving objects)	44	15.20	4	3.65	221.96
Squeezing (Caught in between two objects)	2	0.68	3	2.5	5.07
Contact with electric current/shock	48	16.22	4	4	259.46
Mis-operation of machinery/equipment/tools	51	17.91	4	4.14	296.51
Traffic accidents	44	14.86	4	3.648	216.91
Overworking	2	0.68	2	2.5	3.38
Other reasons of accident	1	0.34	2	2	1.35
Total	**294**	**100**			

VI. RISK RESPONSE TECHNIQUE

There are four basic forms of risk response, as

a. Risk Reduction,
b. Risk Transfer,
c. Risk Avoidance,
d. Risk Absorption.

   - ***a. Risk Reduction***: Sharing risk exposure with other parties.
     e.g. Security deposit.
   - ***b. Risk Transfer:*** Transferring risk does not reduce the criticality of risk, it is just pushed to another party.
     e.g. insurance cost.
   - ***c.*** **Risk Avoidance:** Risk avoidance is associated with refusal for acceptance of risk.
     e.g. use of exemption clauses.
   - ***d. Risk Absorption:*** Risks responsible for repetitive losses can be retained.
     e.g. likely cost of paying for loss, if uninsured. (Roger Flanagan & George Norman, 1993) [9].

The respondents from 55 construction sites details about the probability of occurrence of various risk events. With reference to data collected from sites, the data was analyzed using various Risk Assessment tables. Risk assessment tables are very useful in the risk mitigation strategy.

Calculation Procedure:

- Table 6.1, gives Scale value-I with reference to probability of risk event occurrence.
- Table 6.2, gives Scale Value-II.
- Scale Value-I & Scale Value-II together gives us points of the consequences given in table 6.3.
- Based on the points, category of the risk can be defined which gives risk response action.

Table 6.1: Risk Assessment Table – Likelihood

Description	Scenario	Probability	Scale Value-I
Highly Likely	Very Frequent occurrence	Over 85%	16
Likely	More than even chance	50 - 85%	12
Fairly Likely	Quite often occurs	21 - 49%	8
Unlikely	Small likelihood but could well happen	1 - 20%	4
Very Unlikely	Not expected to happen	Less than 1%	2
Extremely Unlikely	Just possible but very surprising	Less than 0.01%	1

Source:RAMP Handbook [10]

The Scale Value-II in Table 6.2 describes the impact of the particular risk event on the construction project. It is decided based on the responses from the industry experts to the questionnaire.

Table 6.2: Risk assessment Table- Consequence

Description	Scenario	Scale Value-II
Disastrous	Business investment could not be sustained (e.g. Death, Bankruptcy)	1000
Severe	Serious threat to business or investment	100
Substantial	Reduces profit significantly	20
Marginal	Small effect on profit	3
Negligible	Trivial effect on profit	1

Source:RAMP Handbook [10]

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Likelihood of event occurrence (Scale Value-I) and Consequences of the event (Scale Value-II) together can be assessed using Table 6.3.

Table 6.3: Risk Assessment Table- Acceptance of Risk

Likelihood	Consequence				
	Disastrous (1000)	**Severe (100)**	**Substantial (20)**	**Marginal (3)**	**Negligible (1)**
Highly Likely (16)	16000	1600	320	48	16
Likely (12)	12000	1200	240	36	12
Fairly Likely (8)	8000	800	160	24	8
Unlikely (4)	4000	400	80	12	4
Very Unlikely (2)	2000	200	40	6	2
Extremely Unlikely (1)	1000	100	20	3	1

Source: RAMP Handbook [10]

Based on the outcome (points) of table 6.3, table 6.4 provides the action required or risk response plan as shown.

Table 6.4: Key to Acceptance of Risk

Points	Category	Action Required
Over 1000	Intolerable	Must be Eliminated
101 - 1000	Undesirable	Attempt to avoid or transfer Risk
21 - 100	Acceptable	Retain & manage risk
Up to 20	Negligible	Can be ignored

Source:RAMP Handbook [10]

VII. RESULTS OF RISK RESPONSE TECHNIQUE

There are so many factors affecting the occurrence of accidents on a construction site, it is necessary to construct a process that reduces the amount to a manageable few. (HyunSoo Lee et al) [11]. Table 5.1 is the summary of data analyzed using Risk Assessment Tables. It shows that, on an average 'Collapse of temporary structure' falls into Acceptable Category, whereas all the other but one are Undesirable. Mis-operation of machinery/ equipment/ tools is an Intolerable event.

Example of calculation:
Probability of occurrence of Risk Event: 60%
As per Table 4.1, Scale Value-I = 12.
As per Table 4.2, Scale Value-II = 100 (ref. to expert response)
With ref. to Table 4.3, Points of consequences = 1200.
As per Table 4.4, with points over 1000 falls into Intolerable Category.

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Table 7.1: Summary

Risk Event	Score	Category
Drops (Object/tool falls on person from height)	160	Undesirable
Collapse of temporary structure	24	**Acceptable**
Person falling from height	160	Undesirable
Object slips on floor (Impact on stable objects, hits by moving objects)	800	Undesirable
Squeezing (Caught in between two objects)	400	Undesirable
Contact with electric current/shock	800	Undesirable
Mis-operation of machinery/equipment/tools	1200	**Intolerable**
Traffic accidents	160	Undesirable
Overworking	-	
Other reasons of accident	-	

VIII. CONCLUSION

The PRAT is one of the easy mathematical tool to quantify the risks occurrence. Well defined Severity Index (S) and its criterions helps to calculate the Risk Value (R). After complete analysis based on the Risk Value, the urgency level to take required actions can be identified.

The risk assessment with the help of Risk Response Technique is easy way to understand and implement. After thorough analysis of risk events and causes of their occurrence, it is important to select appropriate way for mitigation of risk out of the four suggested.

The analysis using both the methods interprets, 'Mis-operation of machinery/equipment/tools' is very critical event, needs urgent actions to eliminate the consequences. As per PRAT, action must be taken within a month. Whereas the Risk Response Technique identifies it an Intolerable Risk event. All the other undesirable events except collapse of temporary structure are Undesirable. If they are compared with PRAT results, most of them have risk value near 200 points. It implies that, other events also need consideration.

Bases on the outcomes from both the techniques, following corrective actions can be employed depending on the nature of the situation and the level of risk:

- Investigation and reporting on the nature of the emergency.
- Notification of authorities, external investigation and reporting.
- Conduct immediate inspection and rectification depending on risk level.
- Modify work practices, conduct repairs, or remediate areas where necessary.
- Conduct training and induction, issue memos.
- Update procedures and documentation where required.

As a general conclusion, the development of an integrated risk analysis scheme, which will combine a well-considered selection of widespread technique would enable the safety engineers to achieve more efficient results on risk identification.

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BIOGRAPHY

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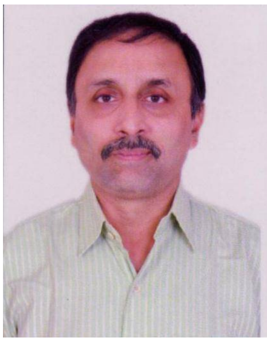

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