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Risk and Its Impact on Quality, Safety and Procurement in Construction Projects

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ABSTRACT
Risk management is an integral part of project management on all construction projects based on knowledge areas of PMBOK. Risk analysis is process of risk which is used to quantify and analyze risks and give the mitigation strategies for each risk. This research was conducted to identify, analyze risks and provide mitigation measures associated with Residential Projects in Bangalore. In this study, risk and its impact were identified and analyzed based on quality, safety and procurement of materials using the questionnaire survey. The impact of project risk was analyzed using qualitative risk analysis like probability of occurrence and impact of each risk based on quality, safety and procurement was found out. Separate risk heat mapping was also created and finally a risk register with risk mitigation measures was provided for impact of risk related to quality, safety, and procurement. Thus, risk management is the best tool for organization to minimize the losses and maximize the benefits in terms of safety, quality and procurement.

Keywords:-*Risk management, probability and impact index, qualitative risk analysis, risk heat matrix.*

INTRODUCTION

Risk management is the process of identification, evaluation, monitoring and minimizing the probability and impact of each risk. RM (Risk Management) has become a timely benefit widely discussed across industries. However, in the construction industry, risk management is not commonly used. More construction companies are not using tools and techniques of risk management but are starting to become aware of the RMP (Risk management process). This shows the fact that the construction industry is becoming to be more cost and time efficient over projects. Risks differ between construction projects due to the fact that every project is unique, especially in the construction industry. Even though there is an awareness of risks and their consequences, some organizations have not influenced the RM methods. In a very uncertain environment, the construction industry was operating, where conditions can change due to the complexity of each project. Risk management is a tool which helps to increase the probability of achieving success and decrease the probability of failure.

There are various types of risks based on internal and external categories. The process of risk management was risk identification by historical data, theoretical analysis, expert options, etc., risk analysis by qualitative and quantitative methods, risk evaluation, risk treatment, and risk monitoring and control [3].

Various literatures were conducted and reviewed. An investigation study concerns with the identification and assessment of risks associated with the Egyptian Non-Residential Buildings Projects. The study explores risk factors probability of occurrence and their effects on cost and time of these projects. It concluded that the design stage risk factors and construction management risk factors were the most influential in the ENRBP of the project [4].

The study to identify the major safety risk factors in Qatari building construction sites and apply risk management technique to assess the impact of these risk factors. A questionnaire was designed based on a comprehensive literature review and feedback from safety engineers working in the Qatari construction industry. The questionnaire responses showed a poor risk management practice in Qatar. The analysis of the questionnaire responses showed that 18 of the selected safety risk factors (out the total 38) were intolerable and needed special attention and care [1].

A case study in a large qualified contractor company in Aceh Province with experience in the construction field for more than 15 years. The research uses primary data collected by using questionnaire. Risk factors associated with project resources include 7 labor factor, 10 material factors, and 17 equipment factors. Analyzed 35 variables which were categorized into three factors of variables which are tested in three periods providing different risk characteristics, both concerning risk probability and risk impact. It has been concluded that ten variables as the most dominant risks that arise simultaneously in all three periods. The labor is a factor with higher frequency and intensity of impact than the other two factors of study [7].
A case of residential building (G+4) Inland Edilon has been taken. Probability and Impact matrix method is used to overcome the identified risk in this project. Analysis is done in Primavera Web as per the available data and results are generated. As per the analysis the total risk impact cost (Waste management strategy, Insufficient land for storage of materials, Insufficient resource availability, Equipment, change in scope of work, Material Delay) is Rs.12,36,572.00/-. After the risk response strategy taken by project risk management team and implemented on the project for minimizing the risk response plan we have achieved is Rs. 3,02,356.6/- [2].

The study was conducted in Residential development in the city of Bangalore, Karnataka. It consists of 16 towers or wings with G+ 18 Floors and 2 basements. It spreads over 23.62 acres and consists of 2, 3, and 4 BHK (Bedroom, Hall and Kitchen) luxury apartments with 126.34m^2, 144.93 m^2 and 153.29 m^2, 213.68 m^2 area.
The Residential development consists of two phases – 1st phase and 2nd phase.

- First phase consists of wing 1 to 7 and wing 16 and
- Second phase includes wing 8 to 14 and wing 15.

Wing 1 to 14 is full of 2 BHK and 3BHK apartments and Wing 15 and 16 consists full of 4 BHK apartments. The number of car parking in the project is nearly 2295 (with wing 1 to 14 is about 1944 and wing 15 and 16 is about 223 respectively).The duration of project is nearly about 56 months. The entire area has full of both hard and soft rocks. The type of soil in the project area is Whitish/Brownish Clayey and Salty sand.

The aim of the work is to quantify and analyze risks that may pose potential threats to project performance in terms of quality, safety, and Procurement (materials) and to manage the risks to

these parameters. The objective of the work is to identify and measure the impact of risk on quality, safety, and procurement (material) and to determine the risk assessment based on above parameters and also to provide the risk mitigation measures based on above parameters.

METHODOLOGY

Various literatures were reviewed to identify the process of finding out the risks and various techniques were assessed to mitigate the risks. The data was collected from the Residential Development in the city of Bangalore, Karnataka.

In case of quality, safety, and material, data was identified in the form of questionnaire survey. The analysis was carried out for various risk identified. In case of Safety and Quality, the analysis such as Qualitative Risk analysis – Probability and Impact Matrix (Risk Heat Matrix) was analyzed and created. In case of Procurement (Material), the analysis such as Qualitative Risk Analysis – Probability Impact Matrix was analyzed, and Process flow Chart was created. Finally, the risk mitigation measures were given for the risk related to Quality, Safety and Procurement (material) identified and the Risk Register was created.

ANALYSIS OF QUESTIONNAIRE SURVEY

Based on the conducted questionnaire in the Site, the probability of occurrence and the impact of each risk was calculated for risk related to quality, safety, and material from 24 respondents. The rating given for probability of occurrence for each risk has the following values:

- 1 – Improbable (Unlikely, though possible)
- 2 – Remote (could occur occasionally)
- 3 – Probable (Not surprised, will occur in given time)
- 4 – Frequent (Likely to occur, to be expected)

The probability or frequency of occurrence responsible for quality, safety and material is computed by using the following formula [1]. Where a_i – constant expressing the weight assigned to each response (ranges from 1 for Improbable to 4 for Frequent); n_i – frequency of each response; N – total number of respondents.

Probability or frequency index (%) = $\frac{\sum_0^4 ai\ ni}{N}$ x 100 (1)

The rating given for the impact on each risk has the following values:

- 1 – Negligible (the hazard will not in serious injury illness, or has a remote possibility of damage)
- 2 – Marginal (the hazard could cause illness, injury, or equipment damage but its effects will not be serious)
- 3 – Critical (the hazard can cause in serious injury or illness, property, or equipment damage)
- 4 – Catastrophic (the hazard is capable of causing death and illness, severe damage to property)

The impact or consequence of each risk responsible for quality, safety and material is computed by using the following formula. Where a_i – constant expressing the weight assigned to each response (ranges from 1 for Negligible to 4 for Catastrophic); n_i – frequency of each response; N – total number of respondents.

Impact or severity index (%) = $\frac{\sum_0^4 ai\ ni}{N}$ x 100 (2)

After the calculation of probability and impact index using the above formulas, the scale used to identify the level of probability and impact should be done. The level of probability and impact index[3] is classified as 0-24% as low risk, 25-49% as Medium risk, 50-74% as High risk, and 75-100% as Severe Risk for the probability and impact index which was shown in Table 1.

Table 1:-*Scale used to identify probability and impact level*

Index level (Scale)	Probability	Impact
0 – 24	Low – 1	Low – 1
25 – 49	Medium – 2	Medium – 2
50 -74	High – 3	High – 3
75 -100	Severe – 4	Severe – 4

RISK IMPACT ON QUALITY

From the responses of questionnaire survey collected from various respondents, the qualitative risk analysis such as the probability and impact analysis in which the probability of occurrence and the impact of each risk related to quality management in the site was determined. After calculating the probability of occurrence and impact of each risk, each risk was ranked using the Descriptive Statistics such as Mean and Standard deviation which was shown in Table 2From the Table 2, the ranking based on Statistical analysis shows that the Rework in construction, Contractors do not purchase the materials on the construction requirement, Excess wastage of steel or other materials, Unavailability of materials as per requirement, Defective material during procurement are the top five risks which affects the quality.

Table 2:-*Ranking of probability and impact index related to quality*

Risk ID	Risk description	Probability		Impact		Mean	S.D	Rank
		%	Degree	%	Degree			
Q8	Rework in construction	68.75	H	77.08	S	4.11	0.492	1
Q11	Contractors do not purchase the materials on the construction requirement	62.50	H	77.08	S	3.85	0.502	2
Q21	Excess wastage of steel or other materials	55.21	H	72.92	H	3.22	0.621	3
Q12	Unavailability of materials as per requirement	47.92	M	83.33	S	3.19	0.628	4
Q16	Defective material during procurement	46.88	M	71.88	H	2.69	0.574	5
Q13	Procurement not arranged in advance according to construction schedule	48.96	M	68.75	H	2.69	0.517	6
Q19	Material deterioration during storage and usage	48.96	M	68.75	H	2.69	0.655	7
Q20	Corrosion of steel	44.79	M	73.96	H	2.65	0.486	8
Q26	Contractors do not select equipment and machinery with advanced technology, production application, and reliable performance and safety to the site	46.88	M	66.67	H	2.5	0.604	9
Q28	Equipment are not selected as per the requirement	41.67	M	71.88	H	2.39	0.546	10
Q10	No coordination with purchase department	44.79	M	64.58	H	2.31	0.708	11
Q22	Mix of reinforcement with different diameters	42.71	M	62.50	H	2.13	0.717	12
Q27	Equipment and machineries not properly calibrated	39.58	M	64.58	H	2.04	0.666	13
Q17	Material data not compared with quality standards	39.58	M	62.50	H	1.97	0.734	14
Q14	No strict inspection of quality items in material procurement	40.63	M	60.42	H	1.96	0.752	15

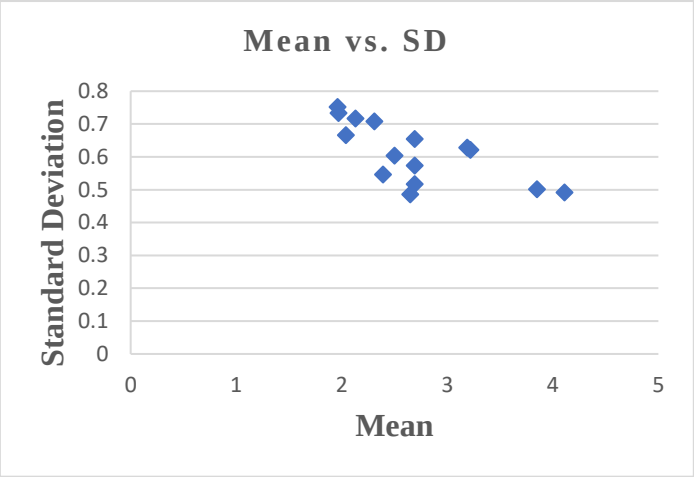


Fig.1:-*Mean vs. Standard Deviation for Probability and Frequency Responses*

A visual indication obtained from the scatter diagram is shown in Figure 1and also shows that data has good compactness, indicating that there is good data consistency on the probability and impact of each risk.

RISK IMPACT ON SAFETY

From the responses of questionnaire survey collected from various respondents, the qualitative analysis such as Probability and Impact Analysis in which the probability of occurrence and the impact of each risk related to safety management in the site was determined. After calculating the probability of occurrence and impact of each risk, each risk was ranked using the Importance Index which was shown in Table 3. From Table 3, the ranking based on the importance index shows that the top five risks for all the 7-category related to safety management in the site.

- With respect to Excavation, Emission of dust, Flying particles of rock, Excessive noise inside the worksite, Improper equipment handling by labours, Stacking of excavated soil on the edge of excavation;
- In case of Bar bending and cutting, No proper wearing of glasses and dust mask, Inadequate inspection, Poor material handling, Over stacking of materials or in unstable manner, Hit of objects with the parts of the body;
- In case of Formwork & shuttering, Lack of experience of labours, Improper shifting of shuttering materials, Difficulty in communication with workers towards safety, improper illumination during deshuttering, Improper stacking of shuttering materials.

Table 3:-*Ranking of probability and impact index related to safety risks*

Risk ID	Risk description	Probability		Impact		Importance index (%)	Rank
		%	Degree	%	Degree		
	Excavation						
E2	Emission of dust	75	S	61.46	H	46.09	1
E6	Flying particles of rock	61.45	H	55.20	H	33.93	2
E9	Excessive noise inside the worksite	66.66	H	45.83	M	30.56	3
E1	Improper equipment handling by labours	63.541	H	47.92	M	30.45	4
E8	Stacking of excavated soil on the edge of excavation	55.20	H	53.12	H	29.33	5
	Bar bending and cutting						
B3	No proper wearing of glasses and dust mask	59.37	H	52.08	H	30.92	1
B4	Inadequate inspection	54.16	H	52.08	H	28.21	2

B2	Poor material handling	59.375	H	46.87	M	27.83	3
B1	Over stacking of materials or in unstable manner	59.375	H	45.83	M	27.21	4
B5	Hit of objects with the parts of the body	54.16	H	41.66	M	22.57	5
	Formwork & shuttering						
FS4	Lack of experience of labours	59.37	H	54.16	H	32.16	1
FS6	Improper shifting of shuttering materials	57.2	H	55.2	H	31.63	2
FS10	Difficulty in communication with workers towards safety	57.29	H	53.12	H	30.44	3
FS11	Improper illumination during deshuttering	57.29	H	52.08	H	29.84	4
FS3	Improper stacking of shuttering materials	62.5	H	46.87	M	29.30	5
	Concreting						
C4	Improper wearing of proper shoes in worksite	55.20	H	55.20	H	30.48	1
C3	Continuous pouring by same person	58.33	H	45.83	M	26.74	2
C2	Improper handling of ingredient	54.16	H	43.75	M	23.70	3
	Movement of Equipment and Machineries						
M9	Improper usage of PPE	56.25	H	59.37	H	33.40	1
M7	Irresponsible attitude of workers during working or handling equipment	60.41	H	55.20	H	33.36	2
M1	Improper handling of equipment by labours	57.291	H	52.08	H	29.84	3
M4	Fall of materials	56.25	H	50.00	H	28.13	4
M2	Equipment operators do not follow the safety rule given by the instructors	57.29	H	48.95	M	28.05	5
	Fall from height						
F5	Minor injuries	66.66	H	40.62	M	27.08	1
F2	Improper covering and protection on opening of floors and roofs	54.16	H	48.95	M	26.52	2
F1	Not wearing of proper safety belts by workers	56.25	H	43.75	M	24.61	3
F3	Inadequate staircases with Stair rails	52.08	H	45.83	M	23.87	4
F4	Major injuries	46.87	M	48.95	M	22.95	5
	Others						
O1	Improper house keeping	58.33	H	51.04	H	29.77	1
O11	Checking of labor safety not done on daily basis	53.12	H	54.16	H	28.78	2
O9	Improper safety training provided	48.95	M	58.33	H	28.56	3
O7	Inadequate lighting for work place	56.25	H	47.91	M	26.95	4
O8	Inadequate water supply in the workplace	57.29	H	46.87	M	26.86	5

In case of Concreting, Improper wearing of proper shoes in worksite, Continuous pouring by same person, Improper handling of ingredient.

- In case of Movement of Equipment and Machineries, Improper usage of PPE, Irresponsible attitude of workers during working or handling equipment, Improper handling of equipment by labours, Fall of materials, Equipment operators do not follow the safety rule given by the instructors.
- In case of fall from height, Minor injuries, Improper covering, and protection on opening of floors and roofs, not wearing of proper safety belts by workers, inadequate staircases with Stair rails, Major injuries.
- In case of Others category, Improper housekeeping, Checking of labor safety not done on daily basis, Improper safety training provided, Inadequate lighting for work place, Inadequate water supply in the workplace are the top risks in each category.

RISK IMPACT ON PROCUREMENT (MATERIAL)

From the responses of questionnaire survey collected from various respondents, the qualitative analysis such as Probability and Impact Analysis in which the

probability of occurrence and the impact of each risk related to Procurement (Material) in the site was determined. After calculating the probability of occurrence and impact of each risk, each risk was ranked using the Importance Index which was shown in Table 4. Table 4 shows the ranking of probability and impact related to procurement (material)

Table 4:-*Ranking of probability and impact index related to material risks*

Risk ID	Risk description	Probability		Impact		Importance index (%)	Rank
		%	Degree	%	Degree		
M6	Insufficient quantity of material is ordered for site	67.59	H	62.96	H	42.5583	1
M10	Delay in receiving of materials on site	67.59	H	59.25	H	40.05487	2
M5	Suppliers do not provide the right quantity of materials at right time	60.18	H	57.40	H	34.55075	3
M17	Mistakes during quantity estimation	61.11	H	56.48	H	34.51646	4
M4	Material Rate fluctuation	62.96	H	46.29	M	29.14952	5
M13	Insufficient stock of materials to level out irregularities of procurement	58.33	H	48.14	M	28.08642	6
M2	Improper tracking of materials	62.96	H	44.44	M	27.98354	7
M1	Improper planning and scheduling of material	50.92	H	48.14	M	24.51989	8
M9	All purchase order transaction are not reliably processed and report	50.92	H	46.29	M	23.5782	9
M18	Shortage and lack of experience of workers	44.44	M	46.29	M	20.57613	10
M8	Purchase orders are not accurately and completely prepared and recorded on timely basis	48.14	M	41.66	M	20.06173	11
M14	Lack of coordination system of withdrawing materials from the stores	49.07	M	36.11	M	17.72119	12
M7	Improper communication between purchase department and other department	45.37	M	38.88	M	17.64403	13
M11	Improper checking and inspection of materials on daily basis	45.37	M	37.96	M	17.22394	14
M3	No Proper communication with the construction site	46.29	M	34.25	M	15.86077	15
M16	Improper disposal of waste	38.88	M	37.96	M	14.76337	16
M12	Improper inward and outward documentation of materials	40.74	M	36.11	M	14.71193	17
M15	Improper handling of materials by the labours	40.74	M	36.11	M	14.71193	18

From the Table 4, the ranking based on the importance index shows that the Insufficient quantity of materials are ordered for worksite, Delay in receiving of materials on site, Suppliers do not provide the right quantity of materials at right time, Mistakes during quantity estimation and Material Rate fluctuation are the top 5 risks which affects the material procurement.

RESULT AND DISCUSSION

The standard risk map which is used to determine the risk zone for each risk related to quality, safety, and procurement (material). The risk map is 4 x 4 matrix with Impact ranging from Low to Severe on the horizontal axis and Probability with the same range on the vertical axis. Four zones are presented in the map: red,

orange, yellow and green zone.
The zones have the following characteristics:

- Red zone: risks in this zone are severe and have critical importance. These are the top priorities and are the risks that a close attention to be paid to them.
- Orange zone: risk in this zone are high importance but extremely rated low as compared to red zone.
- Yellow zone: These are medium level risks. They are not high priority and are associated with devising an alternate strategy to overcome any setbacks throughout the lifetime of an ongoing project.
- Green zone: These risks denote a low weight in the risk assessment matrix and low-level importance and can be ignored [3].

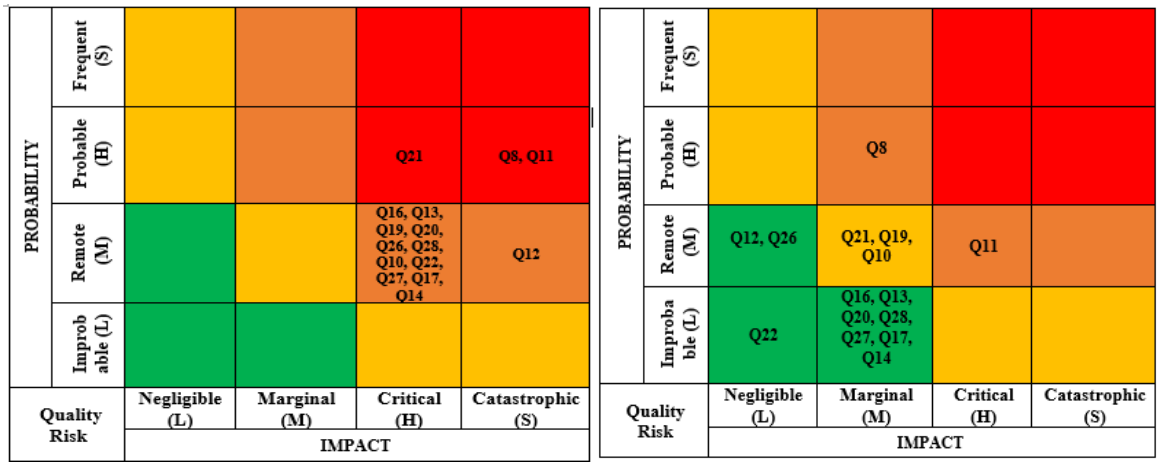
Risk Impact on Quality

After the qualitative risk analysis, the risk register was created in which it contains the current risk i.e. mapped in risk zones before mitigation measures and residual risk i.e., mapped in risk zones after the mitigation measures and risk mitigation strategies are also provided which is shown in Table 5. Table 5 shows that the risk that is high ranked is shown first and measures are given accordingly. The entire risk related to quality was mapped to the risk matrix with impact in horizontal axis and probability in vertical axis and risk matrix before mitigation measures and after mitigation measures was shown in Figure 2(a) and (b).

Table 5:-*Risk Register for Quality*

RISK REGISTER - QUALITY								
Risk ID	**Risk description**	**Current risk**			**Risk mitigation measures**	**Residual risk**		
		P	**I**	**R**		**P**	**I**	**R**
8	Rework in construction	3	4	**12**	Digital technology to automate some of those tedious and typically error-ridden administrative processes, Focus on Collaboration in the Design Phase with BIM.	3	2	**6**
11	Contractors do not purchase the materials on the construction requirement	3	4	**12**	Strategic delivery plan could include purchasing materials in advance themselves, or paying penalty by subcontractors to do and monitoring contractor's performance.	2	3	**6**
21	Excess wastage of steel or other materials	3	3	**9**	Measure exactly so you have the right amount of each material, conduct regular inventory checks, have reuse and recycle bins on site.	2	2	**4**
12	Unavailability of materials as per requirement	2	4	**8**	Accurate purchase request and purchase order should be placed at the accurate time before shortage occurs, order materials based on past experience, Purchase dept should approve and order accurate quantity of material without delay.	2	1	**2**
16	Defective material during procurement	2	3	**6**	Define penalties for excessive defects, Screen suppliers by evaluating their facilities, Supplier qualification audits.	1	2	**2**
13	Procurement not arranged in advance according to construction schedule	2	3	**6**	Plan a time schedule for material delivery and proper material flow process should be maintained, Continuous monitoring is recommended.	1	2	**2**
19	Material deterioration during storage and usage	2	3	**6**	Materials stored at site, depending upon the individual characteristics, shall be protected from atmospheric actions, such as rain, sun, winds and moisture, to avoid deterioration; adequate supervision and skilled labours should be provided while handling.	2	2	**4**
20	Corrosion of steel	2	3	**6**	Avoid exposure to corrosive agents, water, etc; Proper monitoring of metal surface; Metallic Plating and by protective coating.	1	2	**2**

26	Contractors do not select equipment and machineries with advanced technology, production application, and reliable performance and safety to the site	2	3	**6**	Contractors must recommend advanced equipments and machineries. Companies can recommend wearable technologies digitize the workforce, 3D printing shapes the future one layer at a time and advancement of robotics.	2	1	**2**
28	Equipment are not selected as per the requirement	2	3	**6**	Right number of equipment should be selected at right time without delay of work.	1	2	**2**
10	No coordination with purchase department	2	3	**6**	Provide context, Cultivate empathy, Develop a common language, Get involved in other departments' processes, Facilitate consistent communications, Celebrate wins.	2	2	**4**
22	Mix of reinforcement with different diameters	2	3	**6**	To avoid mixing up different sizes of reinforcement, the same diameter of the reinforcement should be provided for all fasteners of a group, separate and monitor each group of different sizes.	1	1	**1**
27	Equipment and machineries not properly calibrated	2	3	**6**	All of this equipment must be properly adjusted and calibrated before performing any measurements. The adjustments and calibrations must be performed to the exact standards of ISO 9001, as well as the recommendations of the manufacturer.	1	2	**2**
17	Material data not compared with quality standards	2	3	**6**	Company purchases materials from external vendors by implementing the QM in Procurement component to support your procurement processes for quality assurance purposes.	1	2	**2**
14	No strict inspection of quality items in material procurement	2	3	**6**	Obtain delivery note, Fill the material inspection form, attach the Material Approval Report (MAR) and finally the joint inspection with the consultant.	1	2	**2**



(a) **(b)**

Fig.2(a):-*Risk Heat Matrix Before Mitigation Measures and* ***(b)*** *Risk Heat Matrix After Mitigation Measures for Quality Risks*

Risk Impact on Safety

After the qualitative risk analysis, the risk register was created in which it contains the current risk i.e. mapped in risk zones before mitigation measures and residual risk i.e., mapped in risk zones after the mitigation measures and risk mitigation strategies are also provided which is shown in Table 6. The entire risk related to safety was mapped to the risk matrix with impact in horizontal axis and probability in vertical axis and risk matrix before mitigation measures and after mitigation measures was shown in Figure 3(a) and (b)

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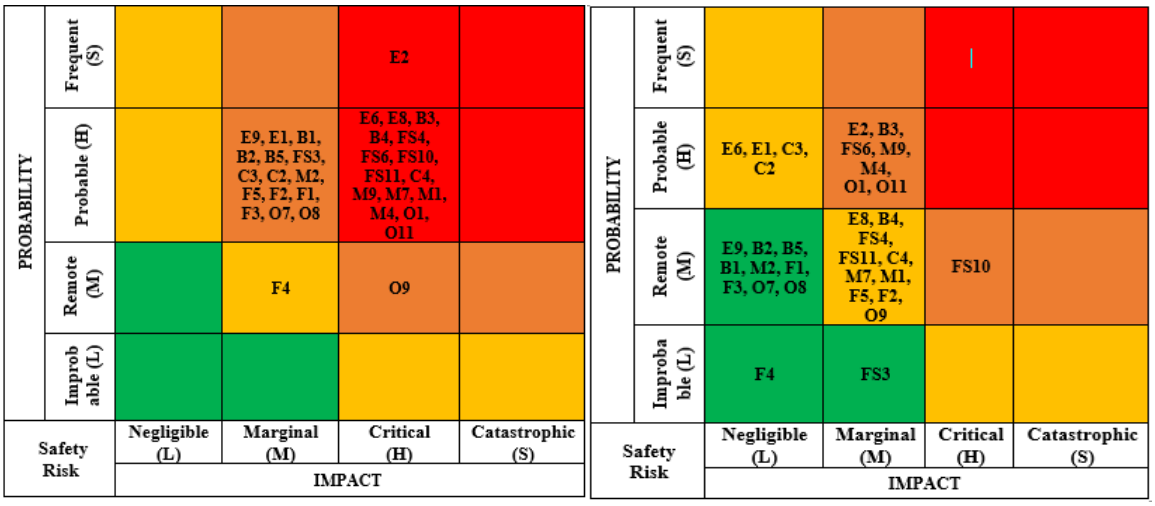
Table6:-*Risk register for safety*

RISK REGISTER - SAFETY								
Risk ID	**Risk description**	**Current risk**			**Risk mitigation measures**	**Residual risk**		
		P	**I**	**R**		**P**	**I**	**R**
EXCAVATION								
E2	Emission of dust	4	3	**12**	Spraying water, Real time monitoring devices like sensors, development of intelligent system for automatic monitoring of dust emissions, Wearing of dust mask.	3	2	**6**
E6	Flying particles of rock	3	3	**9**	Use of eyeglasses	3	1	**3**
E9	Excessive noise inside the worksite	3	2	**6**	Use of ear plugs, Quieter Equipment, Modifying Existing Old Equipment, Barrier Protection, Maintenance, Work Activity Scheduling	2	1	**2**
E1	Improper equipment handling by labours	3	2	**6**	Provide rest periods; information and training to workers on tasks, and the use of equipment and correct handling techniques; well-known and experienced vendors should be chosen.	3	1	**3**
E8	Stacking of excavated soil on the edge of excavation	3	3	**9**	Protection shall be provided by placing and keeping materials or equipment at least 2 feet (.61 m) from the edge of excavations, or by the use of retaining devices that are sufficient to prevent materials or equipment from falling or rolling into excavations.	2	2	**4**
BAR BENDING AND CUTTING								
B3	No proper wearing of glasses and dust mask	3	3	**9**	Conducting safety training and motivation programme regularly.	3	2	**6**
B4	Inadequate inspection	3	3	**9**	Visual examination of the layout pattern, measurement of spacing and counting of bars. The bar diameter and shape, if bent, can be visually checked. Bar spacings, embedments, and bearings on walls or beams are normally checked by measurement.	2	2	**4**
B2	Poor material handling	3	2	**6**	Well experienced and skilled labours, Supervisors shall also take care to assign enough men to each such job depending on the weight and the distance involved.	2	1	**2**
B1	Over stacking of materials or in unstable manner	3	2	**6**	Ensure that stacks are stable and self-supporting, observe height limitations when stacking materials, allow sufficient clearance around stacks for safe handling and easy access.	2	1	**2**
B5	Hit of objects with the parts of the body	3	2	**6**	Workers should be careful while working, unnecessary materials must be disposed off and proper housekeeping is provided.	2	1	**2**
FORMWORK & SHUTTERING								
FS4	Lack of experience of labours	3	3	**9**	Select and train personnel, set standards of performance, handling of formwork has to done properly so it can be reused, Engineer has to check the work done frequently.	2	2	**4**
FS6	Improper shifting of shuttering materials	3	3	**9**	Shifting of right shuttering parts to the net floors avoids missing and collapse of materials	3	2	**6**
FS10	Difficulty in communication with workers towards safety	3	3	**9**	Use both telling and showing methods of training, Use visual methods of communication, Learn the basics of your employee's language, Never raise your voice or over-enunciate your words	2	3	**6**
FS11	Improper illumination during deshuttering	3	3	**9**	Access ways should be suitably lighted and proper regular inspection should be done.	2	2	**4**
FS3	Improper stacking of shuttering materials	3	2	**6**	Materials stacked on well -drained, flat and unyielding surface. It shall not impose any undue stresses on walls or other structures, Materials shall be separated according to kind, size and length.	1	2	**2**
CONCRETING								

C4	Improper wearing of proper shoes in worksite	3	3	**9**	Proper wearing of PPE should be encouraged and consequences occurs must be explained to them.	2	2	**4**
C3	Continuous pouring by same person	3	2	**6**	Shift of workers need to be recommended	3	1	**3**
C2	Improper handling of ingredient	3	2	**6**	Managing the mix with the right quantity of water, adequate inspection	3	1	**3**
MOVEMENT OF EQUIPMENT AND MACHINERIES								
M9	Improper usage of PPE	3	3	**9**	Safety training programmes and importance should be explained.	3	2	**6**
M7	Irresponsible attitude of workers during working or handling equipment	3	3	**9**	After communicating clearly about what you observe and what you expect, provide encouragement and counselling. Provide incentives to perform all work duties with interest and enthusiasm, without complaining or arguing.	2	2	**4**
M1	Improper handling of equipment by labours	3	3	**9**	Employers must permit only thoroughly trained and competent workers to operate, Organising manual handling tasks in a safe way, with loads split into smaller ones, and proper rest periods.	2	2	**4**
M4	Fall of materials	3	3	**9**	Avoid walking or passing during equipment usage.	3	2	**6**
M2	Equipment operators do not follow the safety rule given by the instructors	3	2	**6**	Gifts and incentives to perform with safety rules with interest, explain the importance of injuries that may occur.	2	1	**2**
FALL FROM HEIGHT								
F5	Minor injuries	3	2	**6**	Proper usage of PPE should be followed by workers, Automated real-time clinical diagnosis.	2	2	**4**
F2	Improper covering and protection on opening of floors and roofs	3	2	**6**	Covers should be at least twice the weight of the employee, material or equipment.	2	2	**4**
F1	Not wearing of proper safety belts by workers	3	2	**6**	Proper training methods of wearing, adjusting and interconnecting of equipment; Training record should be maintained.	2	1	**2**
F3	Inadequate staircases with stairrails	3	2	**6**	Inspect stairways for irregularities such as missing steps, loose handrails, corrosion, holes, grease, spills, or loose carpet/rugs. Ropes can also be provided.	2	1	**2**
OTHERS								
O1	Improper house keeping	3	3	**9**	Stairways, walkways, scaffolds, gangways and access ways shall be kept free of building material, tools, accumulated rubbish and obstructions, daily monitoring of work by the safety personnel should be done.	3	2	**6**
O11	Checking of labor safety not done on daily basis	3	3	**9**	Recommendations of the health and safety committee, Previous inspections, Maintenance reports, procedures and schedules, Monitoring reports should be checked once in a week.	3	2	**6**
O9	Improper safety training provided	2	3	**6**		2	2	**4**
O7	Inadequate lighting for work place	3	2	**6**	Measure the average illumination and compare to the recommended levels, Look for shadows over work areas and on stairways, Clean light fixtures regularly. Add more light fixtures in appropriate places.	2	1	**2**
O8	Inadequate water supply in the work place	3	2	**6**	Separate hygenic water plant should be provided for each areas	2	1	**2**



(a) **(b)**

Fig.3(a):-*Risk Heat Matrix Before Mitigation Measures and* ***(b)*** *Risk Heat Matrix After Mitigation Measures for Safety Risks*

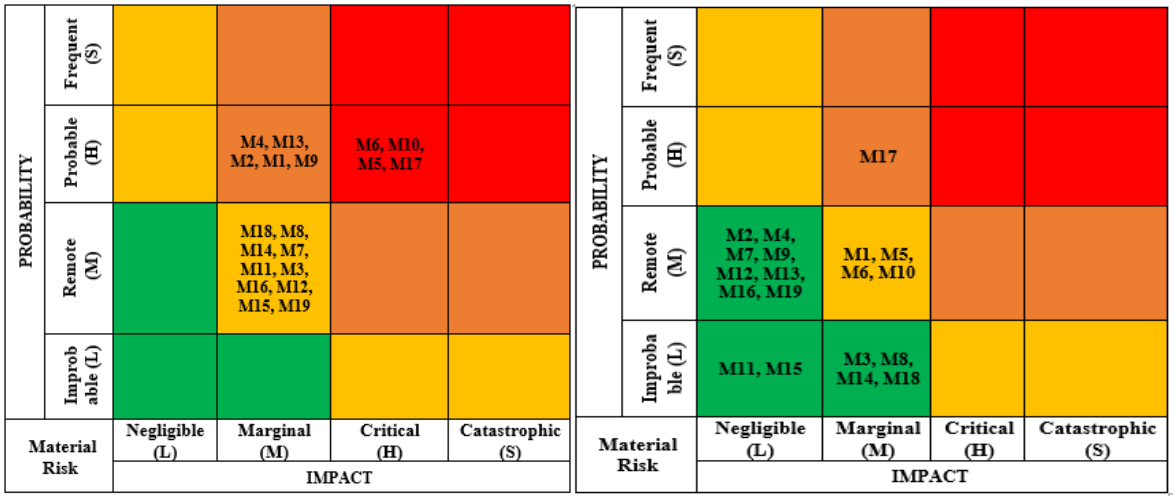
Risk Impact on Procurement (Material)

After the qualitative risk analysis, the risk register was created in which it contains the current risk i.e. mapped in risk zones before mitigation measures and residual risk i.e., mapped in risk zones after the mitigation measures and risk mitigation strategies are also provided which is shown in Table 7. The entire risk related to procurement (material) was mapped to the risk matrix with impact in horizontal axis and probability in vertical axis and risk matrix before mitigation measures and after mitigation measures was shown in Figure 4(a) and (b).

Table 7:-*Risk register for Procurement (Material)*

RISK REGISTER – PROCUREMENT (MATERIAL)									
Risk id	**Risk description**	**Current risk**			**Risk mitigation measures**	**Residual risk**			
		P	**I**	**R**		**P**	**I**	**R**
M1	Improper planning and scheduling of material	3	2	**6**	Development of schedule monitoring and periodic reporting of critical and long lead time	2	2	**4**
M2	Improper tracking of materials	3	2	**6**	Logistics flow and location of materials by using RFID and wireless sensor networks.	2	1	**2**
M3	No Proper communication with the construction site	2	2	**4**	Promote team building communication processes, Promote open communication	1	2	**2**
M4	Material Rate fluctuation	3	2	**6**	Adequate tracking of material rate for monthly basis by a skilled employee	2	1	**2**
M5	Suppliers do not provide the right quantity of materials at right time	3	3	**9**	Progress payments to suppliers must be made on time, Maintain good relationship with suppliers	2	2	**4**
M6	Insufficient quantity of materials is ordered for worksite	3	3	**9**	Accurate purchase request and purchase order should be placed at the accurate time before shortage occurs, order materials based on past experience, Purchase dept should approve and order accurate quantity of material without delay.	2	2	**4**
M7	Improper communication between purchase department and other departments	2	2	**4**	Successful internal purchasing relationships depend on clear communication between purchasing staff and other department make data can easily and accurately convey information.	2	1	**2**
M8	Purchase orders are not accurately	2	2	**4**	Digital procurement solutions should be	1	2	**2**

	and completely prepared and recorded on timely basis				implemented, Cloud procurement systems allow you to create purchase orders, weigh			
M9	All purchase order transactions are not reliably processed and reported	3	2	**6**	contract negotiated prices and terms, manage revisions to documents, and process non-manual supplier invoices.	2	1	**2**
M10	Delay in receiving of materials on site	3	3	**9**	Plan a time schedule for material delivery process, Purchase materials from nearby source with two or more vendors.	2	2	**4**
M11	Improper checking and inspection of materials on daily basis	2	2	**4**	Regular inspection of materials by cross checking of purchase order numbers, daily monitoring of inward and outward of materials, Monitoring of materials by security personnel on daily basis.	1	1	**1**
M12	Improper inward and outward documentation of materials in site	2	2	**4**	Digitalized documentation can be maintained, Proper skilled technicians should be allotted for documentation	2	1	**2**
M13	Insufficient stock of materials to level out irregularities of procurement	3	2	**6**	Theft may occurs so critical material should always be stored in secure locations, advance procurement	2	1	**2**
M14	Lack of coordination system of withdrawing materials from the stores	2	2	**4**	Motivation programs and separate counselling to be conducted within the staffs to solve the problem.	1	2	**2**
M15	Improper handling of materials by the labours	2	2	**4**	Safety education program is to be extended with additional modules and inculcate commitment among management towards safety, well skilled labours to be appointed more to avoid wastage.	1	1	**1**
M16	Improper disposal of waste	2	2	**4**	Regular disposal and monitoring should be done.	2	1	**2**
M17	Mistakes during quantity estimation	3	3	**9**	Conducting a site visit, accurate takeoffs, avoid making uneducated guesses, review the work and subcontractors estimates.	3	2	**6**
M18	Shortage and lack of experience of workers	2	2	**4**	Workers should be appointed based on experience in real-time construction, knowledge on basic information.	1	2	**2**
M19	Wastage due to transportation of materials	2	2	**4**	Quantity of materials should be cross-checked before and after the loading of materials in site so that strict attention of suppliers can be taken to minimize the wastage	2	1	**2**



(a) **(b)**

Fig.4(a):-*Risk Heat Matrix Before Mitigation Measures and* ***(b)*** *Risk Heat Matrix After Mitigation Measures for Material Risk*

The separate material flow process chart created for steel at the month of March and was shown in Table 9.

The summary of process flow chart shows that the operation (approval of order) takes 2 days delay, and for transportation of material, it takes one day delay. Therefore, nearly 3 days was delayed for the entire process of material procurement was shown in Table 8. Thus, Purchase approval should be made as earlier without delay and continuous tracking of material done of regular basis.

Table 8:-*Summary of process flow chart*

Material	***SUMMARY***			
	Material	***Present (days)***	***Proposed (days)***	***Difference (days)***
Steel ***Month*** *March*	*Operation*	*13*	*11*	*2*
	Transportation	*3*	*2*	*1*
	Inspection	*1*	*1*	-
	Totals	*17*	*14*	*3*

Table 9:-*Process flow chart for material procurement*

Date	**Details**	**Operation**	**Transport**	**Inspection**	**Delay**	**Storage**	**Quantity**
	Purchase Requirement	●	⇨	□	D	▽	400 MT
29/02/2020	Estimation – PR	●	⇨	□	D	▽	
01/03/2020	PR – Approval	●	⇨	□	D	▽	
02/03/2020	PR – Approval	●	⇨	□	D	▽	
03/03/2020	PR – Approval	●	⇨	□	D	▽	
04/03/2020	PR – Approval	○	⇨	□	◗	▽	
05/03/2020	PR – Approval	○	⇨	□	◗	▽	
06/03/2020	Purchase department – PO	●	⇨	□	D	▽	400 MT
07/03/2020	PO approval	●	⇨	□	D	▽	
08/03/2020	PO approval	●	⇨	□	D	▽	
09/03/2020	PO approval	●	⇨	□	D	▽	
10/03/2020	Letter of credit	●	⇨	□	D	▽	
11/03/2020	Letter of credit	●	⇨	□	D	▽	
12/03/2020	Steel dispatched	○	⇨	□	D	▽	34 MT
13/03/2020	Vendor - Transportation	○	⇨	□	D	▽	34 MT
14/03/2020	Material delivery at site	○	⇨	□	◗	▽	34 MT
14/03/2020	Material inward verification	○	⇨	■	D	▽	34 MT

CONCLUSION

In this study, the risk and its impact of quality, safety and procurement was identified and analyzed using the probability of occurrence and the impact of each risks and separate risk register with mitigation measures was created for these parameters.

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In case of risk impact on quality, risk heat matrix shows that before mitigation measures, 20% severe risks and 80% high risks was reduced to 13.33% high risks, 20% medium risks, and 66.67% low risks in case of after mitigation measures. With respect to risk impact on safety, risk heat matrix shows that the before mitigation measures, 48.44% severe risks, 48.44% high risks, 3.03% medium risks was reduced to 24.24% high risks, 42.42% medium risks, 33.33% low risks in case of after mitigation measures. Whereas in case of risk impact on procurement (materials), before mitigation measures, 21.05% severe risks, 26.31% high risks, 52.63% medium risks was minimized after mitigation measures to 5.26% of high risks, 21.05% medium risks, and 73.68% of low risks. Finally, for risk impact on material procurement, process flow chart shows that the operation (approval of order) takes 2 days delay, and for transportation of material, it takes one day delay. Therefore, nearly 3 days was delayed for the entire process of material procurement. Thus, Purchase approval should be made as earlier without delay and continuous tracking of material done of regular basis. Hence, the process of risk management helps the organization to sort out the risk related to quality, safety, as well as material and avoid safety related issues, by minimizing the time and cost related issues.

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