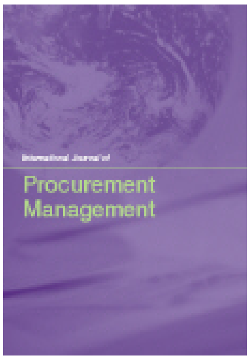

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Focusing on risk and risk management practices in construction projects through the lens of a proposed smart model

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Abstract: This study aims to identify the risk and develop a risk assessment model with SMART function which will *sense* the risk, *monitor* the data with *artificial intelligence*, *activate* the action plan to *rescue* the project, and *trigger* alarms with feedback to the key users, etc., with the help of cloud computing servers. The data was collected from around 150 respondents who are employees of EPC firms. The survey was conducted with a structured questionnaire to analyse risk management practises with reference to the risks involved in construction projects. There are 48 identified risks from various categories as follows: six technical risks, nine financial risks, ten construction risks, eight procurement and supply chain logistics risks, eight legal risks, and eight other associated risks. The results revealed significant risk management practices are adopted in India, focusing first on financial risk, followed by all other risks.

Keywords: construction projects; project performance; risk management practices.

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1 Introduction

Risk is inevitable in any construction project. Risk management practises are the only tool for combating the risks in construction projects. In recent days, post-pandemic issues, novel coronaviruses, and their evolution have hit the Indian economy in many ways. Pre-lock down and post-lock down create an immense impact on the construction industry by means of the movement of labourers from the workplace to their hometowns for various reasons, such as the scare of virus spread or the shortage of accommodation at the site location for the isolation of workers affected by COVID. The resilience of the construction process becomes challenging for the contractors. These are new normal circumstances. The process of risk management included identifying risks, assessing them either quantitatively or qualitatively, choosing the appropriate method for handling them, and then monitoring and documenting them (Patel, 2013). There were 47 types of risk factors identified under the categories of design, physical, logistics, legal, environmental, and management in construction projects (Kishan et al., 2014). The perception of risk by contractors and consultants was mostly based on their intuition and experience. The most commonly utilised risk response measures were risk elimination and risk transfer. However, the respondents revealed that these practises caused delays, low quality, and low productivity in construction projects (Shaikh, 2015). Resolving these issues is quite complex for the contractors due to new kinds of unforeseen risks. Risk always varies from firm to firm. Contractor risk is not an issue or risk for the project owner, and vice versa. Project owner risk is not an issue or a risk to the contractor. Therefore, risk needs treatment to suppress its negative impact. The risk may affect the project’s cost, timeline, quality, and overall performance. Therefore, it is mandatory to sense the occurrence of risk, monitor the progress of the project, activate the action plan to mitigate the risk, and rescue the project in the right direction.

2 Literature review

There was low awareness of the functional use of construction planning tools and techniques, and it was recommended that the use of these tools and techniques be applied in all building projects to manage risks efficiently (Jayasudha and Vidivelli, 2016). In small and medium construction and design, the main factors influencing risk during the construction phase were identified as labour, finance, and material suppliers. Material suppliers and labour were the main factors influencing the risk during the construction phase of large construction projects. They played a major role in influencing the risk of the building during the construction phase (Ramanathan and Rathinakumar, 2017). Construction projects were plagued by physical, construction, financial, design, management, and environmental risks. Risk management introduced to individual large-scale projects could help identify risks in critical activities of the project and plan strategies to avoid them (Varun Raj and Ajith, 2018). An investigation study on combining decision-making and sustainability carried out and according to their study, incorporating several sustainability factors and supplier selection can be helpful for the decision-making process (Mujkić et al., 2019), project success was significantly correlated with risk identification, risk analysis, and risk response, and project success was positively associated with effective risk management in construction projects. Effective improvement in one risk management process affects the other risk management processes positively (Nawaz et al., 2019). The effectiveness of supply chains with centralised and decentralised decision-making, and the Stackelberg's game model is used to determine whether recovery rate and remanufacturing rate can significantly affect the product prices and output of supply chains when the consumer willingness to pay varies were examined (Shu et al., 2019). The cross-country research involved a literature review and a survey of data from managers of global firms. They identified supply chain risk as playing a crucial role. Risk management practises and strategic decisions enable the firm to achieve positive financial outcomes (Singh et al., 2020). Another study which looks the link between successful project management and sustainable project management (Mujkić et al., 2019). The impact of risk management practises on construction project performance in Oman They have analysed the relationship through confirmatory factor analysis, and the results revealed that risk management practises improve performance significantly (ALSaadi and Norhayatizakuan, 2021). Further a study investigated in the building projects in the oil and gas industry, their study aims to examine the effectiveness of civic behaviour and the effectiveness of project implementation (Thirapatsakun and Jarutirasarn, 2021). The current risk management strategies in Yemeni building projects through a survey questionnaire to evaluate the shortcomings in risk management practices (Bahamid et al., 2022). The results broadly support the literature that is already available in terms of identifying the skills needed at various organisational levels with varying hierarchies (Klézl et al., 2022). There are cultural differences in job requirements, and these differences have a significant impact on procurement process and project practice (Stek et al., 2022). For indirect purchasers, a wave of internationalisation and the corresponding need for cultural, communication, flexibility, and agility skills are anticipated, while the responsibility for innovation purchasing is anticipated to grow for direct purchasers (Delke et al., 2023).

3 Research gap and problems statements

This study has been performed to address the gaps in each function, such as engineering and design, manufacturing issues, procurement issues, supply chain and logistic issues, material management issues, installation, testing, and commissioning issues, and operation and maintenance issues during the defect liability period. There will be a definite gap between the tender and project phases, which should be aligned between the organisations and key people involved in the project. Tenders and projects with a high level of criticality due to the contract's lengthy duration and contract value in the billions when key personnel from a tender or project move to other organisations, the situation becomes more difficult. The traceability of the progress and trackability of issues may pile up and create a mess for project organisations during the tender phase and execution. Therefore, data management during front-end engineering design and detail engineering, freezing the material standards and technical specifications, tracking the number of revisions through version control, and procuring the appropriate materials and equipment on time at a negotiated price are necessary to keep a record to track. There are issues in supply chain and logistics like determining the INCOTERMS, material transit across the globe through shipping activities, which involve loading and unloading, therefore tracing the material location from the country of origin, adopting the change in custom duties and taxes, realigning the project plan to secure and optimise the manpower, and other necessary resources. There will be numerous issues that arise during the project's installation and testing phases. Tracking those defects and replacing the defective parts will be critical if the project's overall revenue operation timeline is delayed. Even after the projects have been commissioned, the product may become defective, so it is necessary to track the guarantee and warranty of each part and piece of equipment supplied to the project. Hence, data plays a vital role in any project. Managing those data and analysing the issue to address the risk before it occurs will be difficult, and using artificial intelligence to flag issues for work package owners' consideration is also too complicated in projects. Identifying the risk and mitigating it with appropriate solutions on time will save the project a lot of energy and money. Analysing the abnormalities in the data using cloud computing and data analytics will be a challenge in the near future. The mapping of information function-wise and the correlation of all information through a cloud computing server can be used as input for artificial intelligence to identify the abnormality and respond quickly to the risk in time to mitigate its effects. To propose a detailed solution for developing such a model will be the research gap that needs to be addressed through this study.

4 Objectives of the study

1. To identify the percentage of respondents and their experience level and covariance between a respondent's roles, experience level, and risk.
2. To identify the descriptive statistics of risk management practices with respect to the type of risk involved in construction projects.
3. To identify the variance between the roles of respondents and the type of risk involved in construction projects. Further to identify the impact of overall performance on profitability of the project.
4. To develop a SMART model for risk assessment and risk mitigation in projects.

5 Methodology

This research study was carried out in India. Respondents are employees of EPC firms, selected randomly as a sample, and data was collected from 150 respondents through a field survey with a structured questionnaire for this research. Simple percentage analysis, covariance analysis, descriptive statistics, and two-way analysis of variance methods are used to interpret the results of this research study. A new model, which will be proposed, will reduce the impact of risks on project performance and profitability by identifying them and developing strategies to mitigate them on time.

6 Results and findings

6.1 Profile of respondents

Table 1 shows the demographic information of respondents' roles and experience levels, as well as the percentage distribution between them. Overall respondents $n = 150$.

Table 1 Demographic information of respondents

Role of respondent	*Respondent %*	*Number of respondents*
Project manager	9.33%	14
Construction manager	9.33%	14
Planning engineer	10.00%	15
Construction supervisor	18.67%	28
Warehouse manager	22.67%	34
Procurement manager	20.00%	30
Project finance controller	10.00%	15
Experience level	*Respondent %*	*Number of respondents*
0–5 years	16.67%	25
5–10 years	17.33%	26
10–15 years	16.00%	24
15–20 years	18.00%	27
20–25 years	16.00%	24
Above 25 years	16.00%	24
Total (n)	100%	150

6.2 Covariance between respondent role and experience

Table 2 refers to restructured information with reference to the role of the respondent and their experience level through cross-table reference to analyses covariance between the respondent role (rows) and experience level (columns).

Table 3 indicates the covariance between respondent roles (rows) and Table 4 indicates the covariance between experience levels (columns).

Table 2 Cross tabulation between designation and experience level

Respondent role	*Category of experience of respondent*					
	0–5 years	*5–10 years*	*10–15 years*	*15–20 years*	*20–25 years*	*Above 25 years*
	E1	*E2*	*E3*	*E4*	*E5*	*E6*
Project manager (A)	2	2	4	1	4	1
Construction manager (B)	3	2	5	0	2	2
Planning engineer (C)	2	2	3	5	1	2
Construction supervisor (D)	7	6	1	4	4	6
Warehouse manager (E)	6	7	4	5	8	4
Procurement manager (F)	4	4	5	5	6	6
Project finance controller (G)	1	1	4	4	2	3

Table 3 Covariance analysis between role of respondents

	E1	*E2*	*E3*	*E4*	*E5*	*E6*
E1	4.244898					
E2	4.183673	4.530612				
E3	–1.26531	–1.02041	1.632653			
E4	1.183673	1.816327	–0.73469	3.673469		
E5	3.081633	3.918367	0.387755	1.489796	5.265306	
E6	2.755102	2.673469	–0.73469	2.102041	2.204082	3.387755

Table 4 Covariance analysis between experience levels

	A	*B*	*C*	*D*	*E*	*F*	*G*
A	1.555556						
B	1.222222	2.222222					
C	–0.66667	–0.66667	1.583333				
D	–1.55556	–1.22222	–0.83333	3.888889			
E	0.611111	–0.55556	–1	0.888889	2.222222		
F	0.166667	–0.16667	–0.16667	–0.5	–0.16667	0.666667	
G	7.4E-17	7.4E-17	1.083333	–1.83333	–1.33333	0.5	1.583333

6.3 Descriptive statistics on risk management practices

Table 5 represents the descriptive statistics of the risk management practice score for each type of risk. The median, standard error, standard deviations, kurtosis, and skewness are calculated and indicated in the table.

6.4 ANOVA between respondent role and type of risk

Table 6 represents the cross-table data reference of roles of respondents with respect to the type of risk for analysing the variance between the role and risk type through two-way replications. Table 7 indicates the results of two ANOVA.

Table 5 Descriptive statistics of risk management practices

	Technical	*Financial*	*Construction*	*Procurement ad supply chain*	*Legal*	*Other associated*
Mean	5.7	6.38	5.7	5.733333	5.713333	5.14
Standard error	0.142446	0.193096	0.17462	0.189823	0.204936	0.211319
Median	6	7	6	6	5	5
Mode	7	8	6	3	3	3
Standard deviation	1.744599	2.364928	2.13865	2.324849	2.509944	2.588125
Sample variance	3.043624	5.592886	4.573826	5.404922	6.299821	6.698389
Kurtosis	0.109496	–0.84188	–0.61494	–1.03254	–1.19143	–1.17592
Skewness	–0.12913	–0.39868	–0.22781	0.192231	0.14187	0.25794
Range	9	9	9	9	9	9
Minimum	1	1	1	1	1	1
Maximum	10	10	10	10	10	10
Sum	855	957	855	860	857	771
Count	150	150	150	150	150	150
Largest (1)	10	10	10	10	10	10
Smallest (1)	1	1	1	1	1	1
Confidence level (95%)	0.281475	0.381559	0.345052	0.375093	0.404956	0.41757

Table 6 Cross tabulation between role and type of risk

Role (Factor A)/risk type (Factor B)	*Technical risk E1*	*Financial risk E2*	*Legal risk E3*	*Procurement risk E4*	*Logistic risk E5*	*Construction risk E6*	*Political risk E7*
Project manager (A)	1	3	4	0	0	1	5
Construction manager (B)	0	0	1	0	1	10	2
Planning engineer (C)	9	0	0	2	4	0	0
Construction supervisor (D)	3	0	1	1	1	17	5
Warehouse manager (E)	3	3	9	2	11	2	4
Procurement manager (F)	3	1	3	13	3	3	4
Project finance controller (G)	0	10	1	1	2	1	0

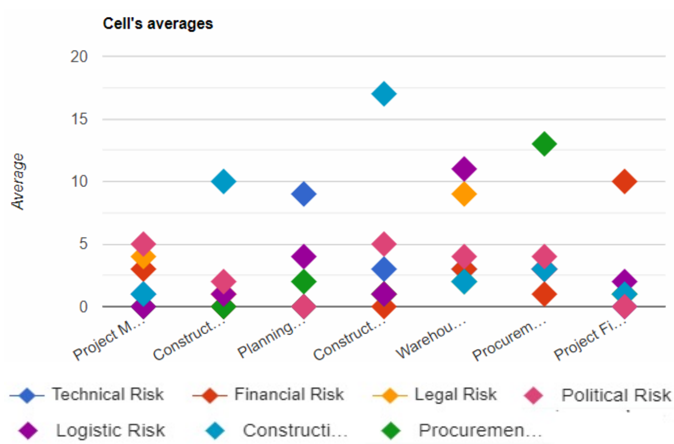
Two sample ANOVA – fixed test, using F distribution (right-tailed), role of respondents factor – A, H0 hypothesis, since the p-value > α, H0 cannot be rejected. The averages of all groups assume to be equal. In other words, the difference between the averages of all groups is not big enough to be statistically significant. A non-significance result cannot prove that H0 is correct, only that the null assumption cannot be rejected. P-value, the p-value equals 0.679, ($P(x \leq 0.664) = 0.321$). It means that the chance of type I error, rejecting a correct H0, is too high: 0.679 (67.9%). The larger the p-value the more it supports H0.

- Test statistic: the test statistic FA equals 0.664, which is in the 95% region of acceptance: [$-\infty$: 2.3638].
- Effect size: the observed effect size $\eta 2$ is medium, 0.1. This indicates that the magnitude of the difference between the averages is medium.

Table 7 Analysis of variance results

ANOVA						
Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit.*
Rows	66.81633	6	11.13605	0.6640076	0.678975	2.36375096
Columns	28.2449	6	4.707483	0.2806923	0.942353	2.36375096
Error	603.7551	36	16.77098			
Total	698.8163	48				

Figure 1 Indicating computed results of each risk types (see online version for colours)



Risk type factor – B results as follows, H0 hypothesis since the p-value > α, H0 cannot be rejected. The averages of all groups assume to be equal. In other words, the difference between the averages of all groups is not big enough to be statistically significant. A non-significance result cannot prove that H0 is correct, only that the null assumption cannot be rejected.

- P-value: the p-value equals 0.9424, ($P(x \leq 0.2807) = 0.05765$). It means that the chance of type I error, rejecting a correct H0, is too high: 0.9424 (94.24%). The larger the p-value the more it supports H0.
- Test statistic: the test statistic FA equals 0.2807, which is in the 95% region of acceptance: [$-\infty$: 2.3638].
- Effect size: the observed effect size $\eta 2$ is small, 0.045. This indicates that the magnitude of the difference between the averages is small.

Figure 2 Residualas: Q-Q plot (see online version for colours)

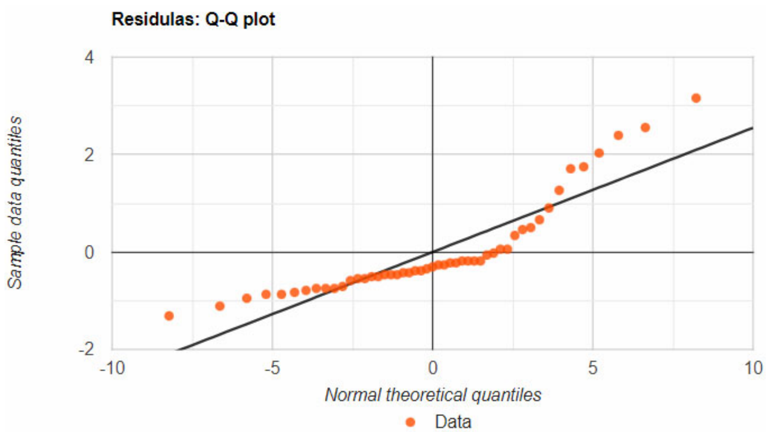
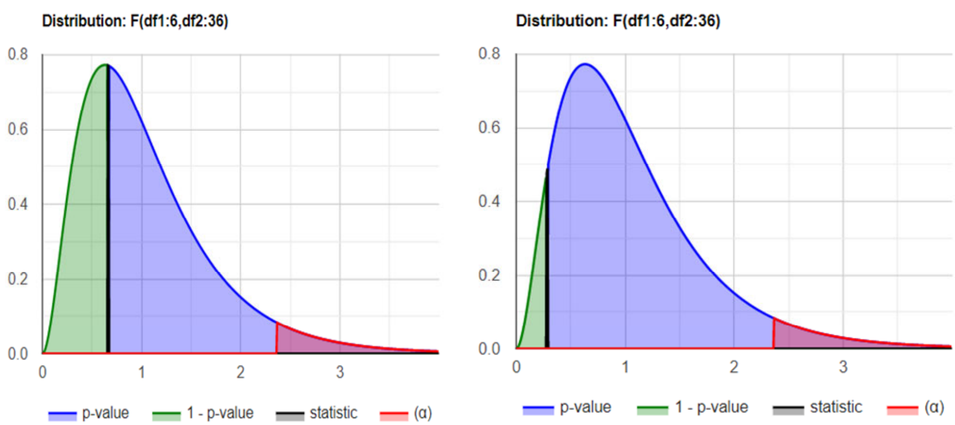


Figure 3 Distribution diagram p-value and significance α (see online version for colours)



6.5 Covariance between respondent role and type of risk

Table 8 indicates the covariance between respondent roles (rows) and Table 9 indicates the covariance between risk types (columns).

Table 8 Covariance analysis between role of respondents

	A	*B*	*C*	*D*	*E*	*F*	*G*
A	3.428571						
B	–0.57143	11.14286					
C	–3	–3.71429	9.836735				
D	–1	18	–3.85714	30.57143			
E	0.285714	–2.85714	0.306122	–7.28571	11.26531		
F	–2.71429	–2.28571	0.102041	–3	–3.67347	13.34694	
G	0.714286	–2.42857	–3.16327	–5.57143	–1.12245	–4.18367	10.69388

Table 9 Covariance analysis between risk types

	E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E7*
E1	8.204082						
E2	–4.44898	11.10204					
E3	–1.22449	0.836735	8.204082				
E4	2.061224	–2.44898	1.061224	18.20408			
E5	3.040816	0.367347	7.469388	1.755102	11.83673		
E6	–3.61224	–8.65306	–4.7551	–4.46939	–6.69388	34.12245	
E7	–1.46939	–2.5102	2.959184	1.530612	0.020408	4.693878	4.122449

6.6 Linear regression analysis – influence of overall performance on profitability in construction

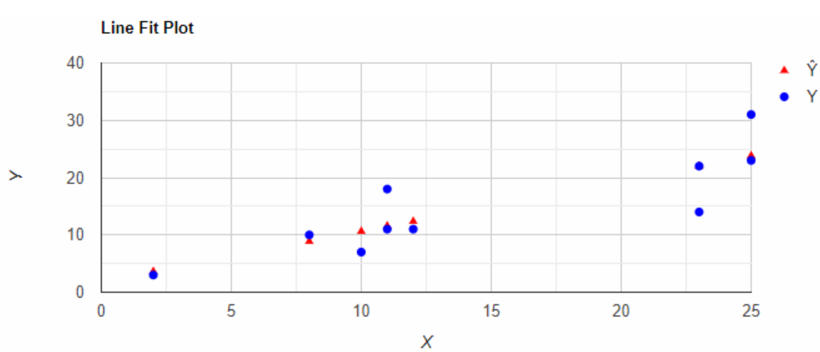
Regression line equation: $\hat{Y} = 1.8873 + 0.8742X$ where X is overall performance and Y profitability of execution. X predicted Y, $R^2 = 0.73$, F (1, 8) = 21.22, $p = 0.002$.

$\beta = 0.87$, $p = 0.002$.

Table 10 Linear regression results

Source	*DF*	*Sum of square*	*Mean square*	*F statistic (df_1, df_2)*	*P-value*
Regression (between $\hat{y}_i$ and $\bar{y}$)	1	467.6879	467.6879	21.2209 (1, 8)	0.00174
Residual (between y_i and $\hat{y}_i$)	8	176.3121	22.039		
Total (between y_i and $\bar{y}$)	9	644	71.5556		

Figure 4 Regression line: line fit plot (see online version for colours)



- Y and X relationship: R square (R2) equals 0.7262. It means that 72.6% of the variability of Y is explained by X. correlation (R) equals 0.8522. It means that there is a very strong direct relationship between X and Y.
- Goodness of fit: overall regression: right-tailed, F(1,8) = 21.2209, p-value = 0.00174. Since p-value < α (0.05), we reject the H0. The linear regression model, $Y = b0 + b1X + \varepsilon$ provides a better fit than the model without the independent variable resulting in, $Y = b0 + \varepsilon$.

- The slope (a): two-tailed, T(8) = 4.6066, p-value = 0.00174. For one predictor it is the same as the p-value for the overall model. The Y-intercept (b): two-tailed, T(8) = 0.5879, p-value = 0.5728. Hence, b is not significantly different from zero. It is still most likely recommended not to force b to be zero.
- Residual normality: the linear regression model assumes normality for residual errors. Shapiro will p-value equals 0.3453. It is assumed that the data is normally distributed.

Figure 5 Regression line: residual plot (see online version for colours)

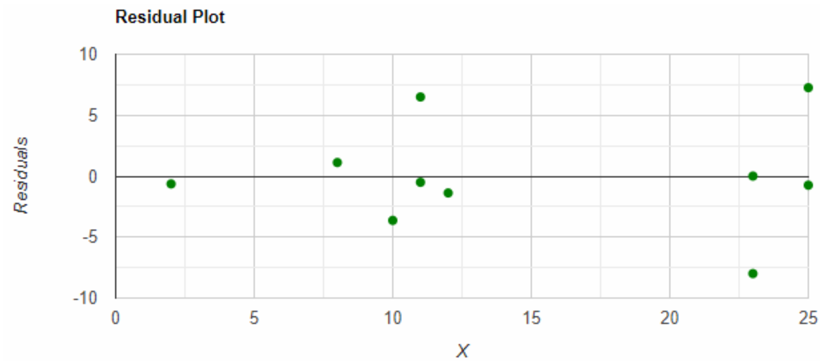
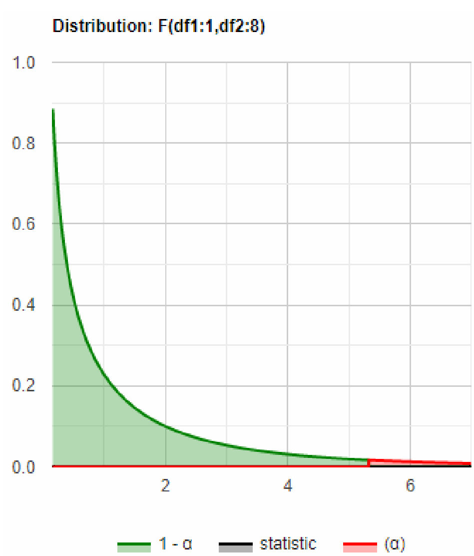


Figure 6 Distribution-degrees of freedom (see online version for colours)



6.7 Discussion on risk involved in construction project

There are 48 risks identified in this research study. There are six risks that fall under technical risk, such as:

1 design error and calculation flaws

2 specification changes

3 material over run

4 equipment size and ratings changes

5 quantities over run

6 failures on integration.

The previous studies carried out also propose an artificial neural network approach for cost estimation of engineering services (Matel et al., 2022).

There are nine risks that fall under financial risk, such as:

1 pandemic prevention extra cost

2 liquidity damages

3 extension of time

4 Forex changes impacting cost of import items

5 change in law

6 tax revision and custom duty revision

7 items under firm prices

8 cash flow issues

9 termination of contract due to performance issues.

The current study is also consistent with the previous studies carried out and reveals that there were 47 types of risk factors identified under the categories of design, physical, logistics, legal, environmental, and management in construction projects (Kishan et al., 2014).

There are ten risks that fall under construction risk, such as:

1 labour issues

2 material defects

3 methodology errors

4 erection accidents

5 plants and tools failure

6 heavy construction equipment failures

7 improper overlaps in planning

8 delay due to natural calamities

9 missing resources

10 material wastages.

Figure 7 Residuals normality histogram (see online version for colours)

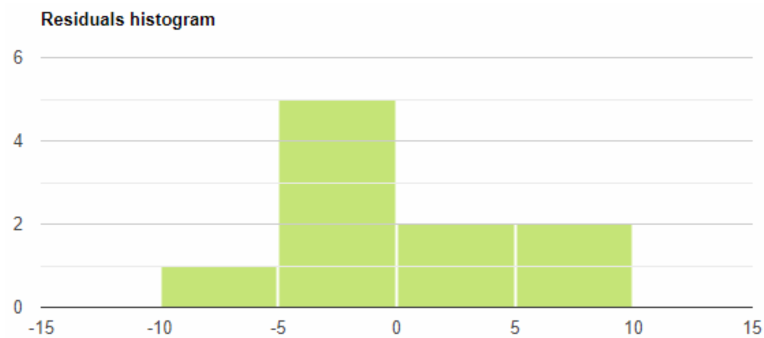
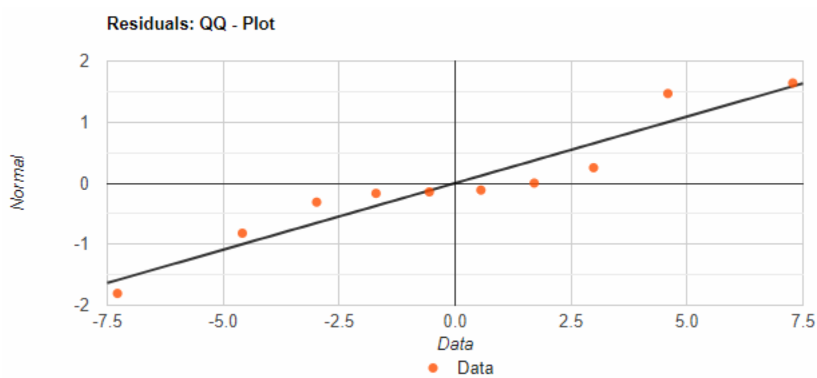


Figure 8 Residuals normality: QQ-plot (see online version for colours)



These results are also consistent with the findings and proposal for a digital maturity assessment framework for construction site operations (Wernicke et al., 2021).

There are eight risks that fall under procurement and logistics risk, such as:

1 material damages during logistics transit

2 delivery delay

3 factory acceptance test and type test delays

4 commodity price flucations

5 transit damages at manufacturer place

6 spare parts issue

7 manufacturing approval delay

7 delay due to price negotiation during selection of suppliers.

There are eight risks that fall under legal risk, such as:

1 arbitration with customer

2 litigation with suppliers or manufacturers

3 defect liability issues and disputes
4 unethical act/practices to get payments
5 provisional sum issues
6 failure to adhere contract clauses
7 failure of payments
8 claims on loss on revenue operation by customer.

There are eight risks that fall under other risks, such as fund issues from

1 lending agency
2 political risk
3 geographical and environmental risk
4 labour protest
5 social risk
6 casualties during installations
7 public policy amendments
8 new normal pandemic situations.

These results are also consistent with the previous studies performed to identify the impact of poor communication on dispute occurrence in the Yemeni construction industry (Gamil and Abd Rahman, 2022).

7 Proposed smart model to address problems

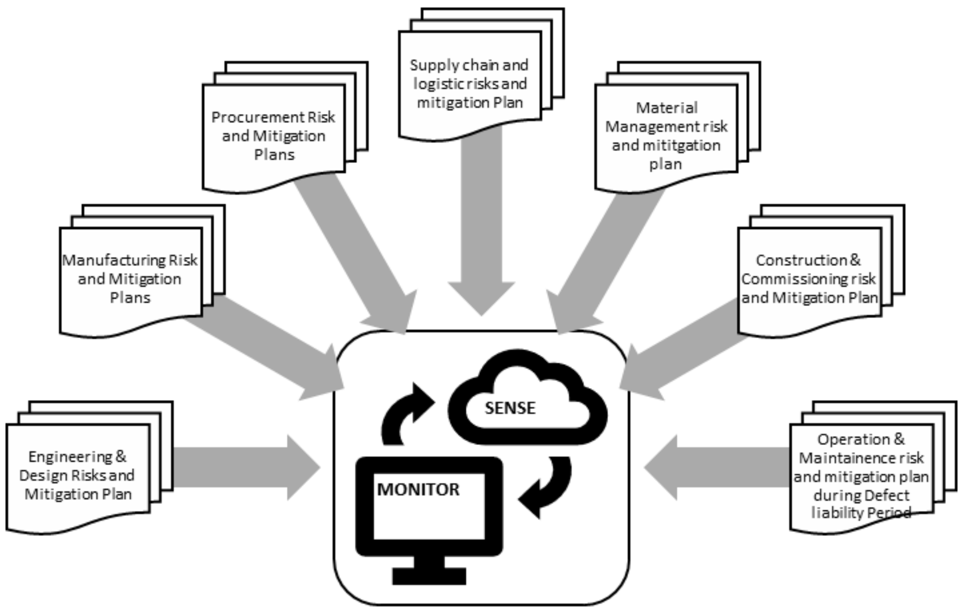
7.1 Smart cloud server

A cloud computing server will be used for feeding and retrieving data via QR codes and barcode links, which serves the data whenever needed to alert the user and take action on the risk mitigation plan, as shown in Figure 10. The smart server will sense the data when it enters its module and monitor the data perpetually as indicated in Figure 9. A comparative check algorithm will be used that works similar to the comparator in that it reads the standard reference data fed during the tender stage and compares it with the actual data fed during the implementation stage. As a result, when it detects abnormalities using the running algorithm fed into the server to perform cloud computing, it will determine and detect the need to initiate the action plan. Furthermore, as shown in Figure 10, it assists immediately by initiating the rescue action and triggering an alarm for the server and web user. The inflow and outflow through the SMART cloud servers are shown in Figure 11.

7.2 Engineering and design unit

Engineering and design data evolution history with version date and validation layout, scheme drawings, bill of materials, bill of quantity, life cycle, failure rates, frequency of failure, reliability and availability information, repair schedules, tender specifications, supplier technical complaints, as-built drawing details, design life, and other technical waivers will be fed into the cloud server.

Figure 9 Sensing *real data* and *monitoring abnormality through risk registers*



7.3 Smart functions unit

Information will be fed by each unit into a share point, and then barcode and QR code generation will be done for each product or piece of equipment with an asset code and server access linked with a secure code for each function fed into the building information modelling system to track and trace information flows.

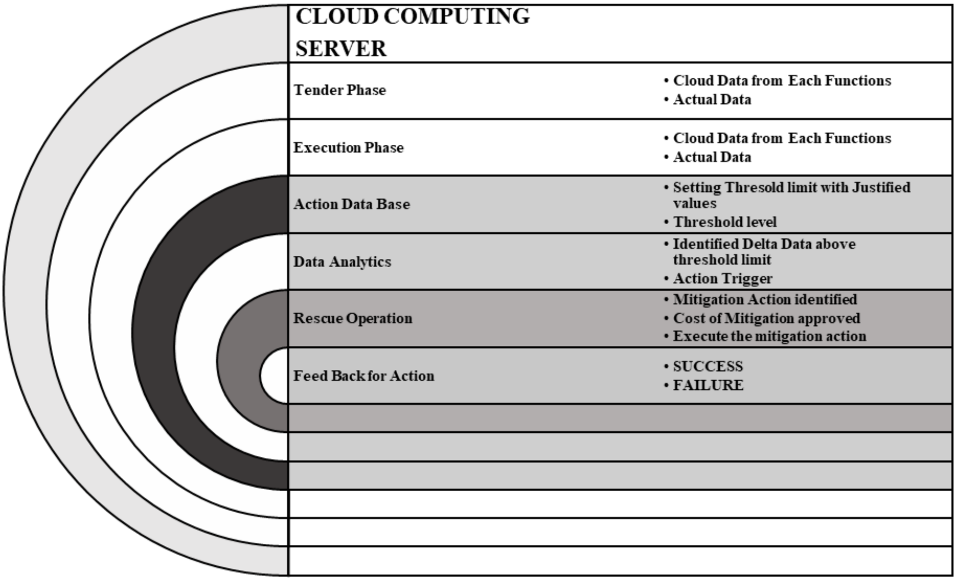
7.4 Manufacturing unit

Manufacturing clearance records, factory test validation reports, and QA/AC certificates for each individual product and piece of equipment will be fed into the cloud server.

7.5 Procurement unit

Procurement data, purchase order details, supplier contact details, serial number and part number, catalogue references, country of origin, custom duty and tax details, alternate supplier details, guarantee and warranty details, and defect liability period of each item will be fed to the cloud server for each individual product and piece of equipment.

Figure 10 Activating action plans and rescue impact with triggers (SMART)



7.6 Supply chain unit

Purchase order reference, serial number, part number, INCOTERMS, insurer details, logistics slot or batch, packing details, loading and unloading port details with date and time Tiltometer, transit diagonalise through graph information, outbound delivery (OBD) transit tracker details, HSN code, waybills, delivery challans, etc. will be fed into the cloud server.

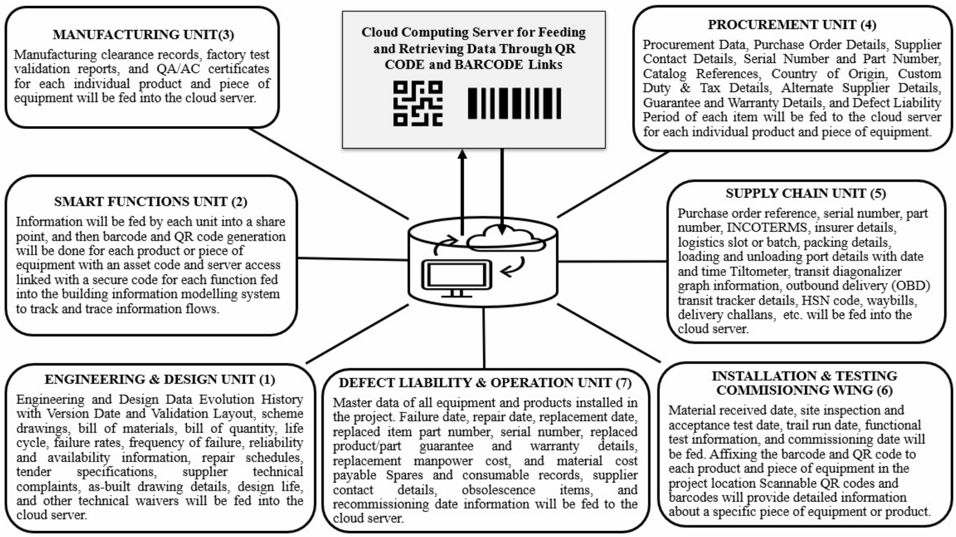
7.7 Installation and testing commissioning wing

Material received date, site inspection and acceptance test date, trail run date, functional test information, and commissioning date will be fed. Affixing the barcode and QR code to each product and piece of equipment in the project location scannable QR codes and barcodes will provide detailed information about a specific piece of equipment or product.

7.8 Defect liability and operation unit

Master data of all equipment and products installed in the project. Failure date, repair date, replacement date, replaced item part number, serial number; replaced product/part guarantee and warranty details, replacement manpower cost, and material cost payable spares and consumable records, supplier contact details, obsolescence items, and recommissioning date information will be fed to the cloud server.

Figure 11 Research model *sense, monitor, action, rescue, trigger* (SMART) with cloud computing and storage



8 Conclusions

There are 48 risks identified under six categories of risk as follows, technical – six risks, financial – nine risks, construction – ten risks, procurement and supply chain logistics – eight risks, legal – eight risks, and other associated risks – eight risks. The sum of score rates shows that construction firms adapted risk management to prevent financial risk (957), procurement risk (860), legal risk (857), technical risk (855), construction risk (855) and other associate risks (771) respectively. Furthermore, the sum of score rates also shows that construction firms are keen to adopt project cost control (888), overall performance (870), on-time delivery (853), and profitability on execution (803) to improve project performance through risk management practice. The results, findings and discussions are limited to region of study and response received from respondents.

Future research in this area could include creating a structural equation model (SEM) to examine structural relationships among factors affecting risks in construction projects at various stages, as well as the efficiency and outcomes of risk management practices in construction projects across India, Asia-Pacific, and the global scenario. The results may be compared to identify the common risk across various projects and risk management practices. Similarly, the risk factors may be different for projects, and the same may be analysed to improve the risk management strategies to increase the performance of the project and profitability of the EPC firm.

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