Development of Regression Model for Project Risk Prioritization of Building Construction Projects

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Abstract

FMEA is a proactive process which aims to evaluate a system, design and to tackle the failures in all possible ways, In the FMEA procedures, a numerical value is assigned to each risk which has a potential to cause a failure using Severity (S), Occurrence (O) and Detection (D) indices and a Risk Priority Number (RPN) is obtained by multiplying three numerical values. This paper analyses the risks in a construction project by preparing a qualitative scale for all such identified risks and a multiple regression analysis model is developed for predicting the RPN values.

Key words: *FMEA- RPN- Occurrence- Detection- Severity- qualitative- design*

Introduction

FMEA is a tool for reliability wherein it requires identifying failure modes of various broadly classified risks associated with the construction project. This paper provides general guidance in the application of FMEA. Firstly, the potential of failure modes and its causes are identified and suitable mitigation measures are determined. Later on, RPN for each failure mode is calculated and proposed actions are recommended top reduce the RPN. The basic steps are to identify the root cause and potential problems that could occur and their calculated RPN values which give an idea as to the area where concerted effort is needed to reduce the occurrence of such risks.

Traditional FMEA Approach

FMEA for this project was carried out by cross functional team of experts from various departments. The team was constituted at the planning stage of the project based on the engineering approach that is followed presently. The team analyzed various parameters for occurrence of risks and their causes and effects were determined. The failure of risks identified under each mode was obtained by way of questionnaires from 5 individuals who were considered as experts in the concerned area. This is shown in table….1.

The failure of risks identified under each mode was prioritized based on the RPN. RPN is a decision factor based on Severity (S), Occurrence (O) and Detection (D).These numbers are scaled between 1 & 10 as given in the table2 .RPN is calculated for all the risks under each mode which may cause failure. Higher the RPN, higher is the risk of failure. From RPN, a critical summary is drawn up to highlight the areas where action is mostly needed.

TABLE 1: Ranking Scale for Severity, Occurrence and Detection Indexes

Rank	**Severity (S)**	**Occurrence (O)**	**Detection (D)**
10	Hazardous without warning	Extremely high	Absolutely uncertain
9	Hazardous with warning	very high	very remote
8	very high	high	remote
7	high	frequent	very low
6	moderate	moderate	low
5	low	occasionally	moderate
4	very low	slight chance	moderately high
3	minor	very slight chance	high
2	very minor	remote, very unlikely	very high
1	none	extremely remote	Almost certain

Table 2: Potential Failure Modes and Prioritization of RPN for Project Risk

Failure	Cause	Control mechanism	S	O	D	RPN
Design Risk	Design Errors and omissions	Engage experienced designers under the supervision of chief designer	10	8	4	320
			10	7	5	350
			10	7	4	280
			10	8	5	400
			10	7	3	210
	Design Process takes longer than anticipated	outsource it	8	6	4	192
			7	6	5	210
			8	6	4	192
			8	7	4	224
			8	6	3	144
	Stake holders request late changes	to extent not to entertain	6	6	5	180
			6	7	5	210
			7	8	6	336
			7	7	6	294
			6	7	7	294
	Failure to carry	engaged well	6	6	5	180

	out the works in accordance with the contract	qualified resources	6	7	5	210
			7	8	6	336
			7	7	5	245
			7	7	7	343

Table 2: Potential Failure Modes and Prioritization of RPN for Project Risk

Failure	Cause	Control mechanism	S	O	D	RPN
External Risks	New stakeholders emerge and request changes	Apply strategy	8	4	4	128
			7	5	4	140
			8	5	4	160
			8	7	5	280
			9	6	4	216
	Public objections	Resolve objections amicably	6	2	2	24
			6	2	1	12
			7	4	2	56
			8	4	2	64
			7	5	2	70
	Laws and Local standards changes	Suitable risk allowance has to be incorporated in the budget	6	2	4	48
			6	3	5	90
			7	3	5	105
			7	4	4	112
			8	3	5	120
	Tax change	Suitable risk allowance has to be incorporated in the budget	8	2	5	80
			9	5	6	270
			9	6	6	324
			8	5	4	160
			8	6	5	240
Environmental risks	Environmental analysis incomplete	Suitable environmental mitigation measures has to be adopted	8	4	3	96
			8	5	4	160
			8	6	4	192
			8	7	3	168
			9	5	6	270

	New alternatives required to avoid, mitigate or minimize environment impact	Suitable environmental mitigation measures has to be adopted	8	4	3	96
			9	6	2	108
			8	5	2	80
			8	5	3	120
			8	5	3	120

Table 2: Potential Failure Modes and Prioritization of RPN for Project Risk

Failure	Cause	Control mechanism	S	O	D	RPN
organizational risks	Inexperienced workforce and staff turnover	training and development has to be imparted	6	6	2	72
			7	6	2	84
			7	5	2	70
			8	4	3	96
			7	3	4	84
	Delayed deliveries	Rescheduling has carried on realistic basis	6	6	6	216
			7	6	6	252
			8	7	6	336
			8	6	7	336
			9	8	5	360
	Lack of protection on a construction site	Effective and suitable protective measures need to be incorporated	8	4	4	128
			9	6	4	216
			9	5	3	135
			9	5	2	90
			7	4	4	112
Project management risks	Failure to comply with contractual quality requirements	rework has to be carried out at the cost of contractor	8	6	5	240
			10	8	6	480
			9	8	6	432
			10	7	5	350
			8	7	6	336
	scheduling errors, contractor delays	Rescheduling has carried on realistic basis	8	8	5	320
			10	7	5	350
			9	8	6	432
			10	8	5	400
			9	7	6	378
	Project team	Best HR	6	6	5	180

	conflicts	pracices to practiced without being detrimental to the progress of the project	7	6	5	210
			8	6	4	192
			7	5	3	105
			8	5	2	80

Table 2: Potential Failure Modes and Prioritization of RPN for Project Risk

Failure	Cause	Control mechanism	S	O	D	R
Right of way risks	expired temporary construction permits	Obtain the re-approval/s	8	2	1	16
			8	4	1	32
			9	6	2	108
			9	6	1	54
			9	6	2	108
	contradictions in the construction documents	To be resolved amicably	6	4	2	48
			6	5	1	30
			7	5	2	70
			8	6	2	96
			7	6	2	84
construction risks	construction over runs	Rescheduling has carried on realistic basis, tight leash on the budget	8	8	6	384
			10	9	7	630
			10	8	7	560
			9	8	7	504
			8	7	6	336
	technology changes	Adoption of changing technology and engaging hands on experienced people	8	4	5	160
			10	7	7	490
			9	8	6	432
			9	7	6	378
			9	8	6	432

Multiple Regression Analysis

This application involves an investigation of the factors that affect the RPN. The study involved multiple regression models as a means of relating the dependent variable RPN to three independent variables S, O & D. The dependent variable RPN (Y) is written as a function of three variables as mentioned above in a linear model. The random error term is added to make the model probabilistic as compared to being deterministic.

The form of multiple regression model is $Y = A_0 + A_1 * S + A_2 * O + A_3 * D$ where Y is the dependent variable RPN and A_0 , A_1 , A_2 , A_3 are unknown model parameters and needs to be evaluated. To fit the model, a sample of 100 RPN values from 7 failure modes is taken and they are presented in table…..

Summary of Output

Table 3: Regression Statistics

Multiple R	0.9702
R Square	0.9412
Adjusted R Square	0.9394
Standard Error	33.7659
Observations	99

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	1734818.075	578272.6916	507.1977	2.5982E-58
Residual	95	108312.6121	1140.132759		
Total	98	1843130.687			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-413.4938776	23.32328092	-17.72880406	6.88E-32	-459.79644	-367.191	-459.796	-367.191
10	30.23791892	3.185760181	9.491586684	2.02E-15	23.913385	36.56245	23.91339	36.56245
8	32.93942802	2.711288173	12.14899558	4.75E-21	27.556840	38.32202	27.55684	38.32202
4	46.11163415	2.415496641	19.08991855	2.8E-34	41.316267	50.907	41.31627	50.907

Multiple regression analysis was carried out using MS-Excel package. The print out of the same is presented in table 3.

1) The least square estimates of the parameters are:
   A_0 = -413.49 A_1 = 30.238 , A_2= 32.94 , A_3= 46.112
2) The minimum value of sum of squared errors (S.S.E.) is 108312.61.
3) Variance = SSE / (n-4) where n is the sample values and 4 is the unknown parameters to be found. Variance = (108312.61)/ (100-4) =

1140.13 which is presented in the output table.

Hence, SD = √ variance = √1140.13= 33.76 which has been displayed in the output table.

Conclusion

1. The regression equation can be written as
    a. RPN = - 413.494 + 30.238(S)+32.94(O)+46.112(D).
2. As a sample check, the first value of RPN in table 2 with values of S=10 O= 8 & D=4 is substituted in the above regression equation and the value works out to 337 which is nearer to the observed value.
3. In multiple regressions, the model takes the form of an equation that contains a coefficient (B) for each predictor. The first part of the table gives us estimation for these B values and these values indicate the individual contribution of each predictor to the model.
4. The B value gives the relationship between RPN and each predictor. If the value is positive, then there is a positive relationship between the outcome and the predictors, whereas a negative coefficient represents a negative relationship. From the data shown in the Table 3, all the three predictors have positive B values indicating positive relationship.
5. The data points are independent and predictors (severity, occurrence and detection) have positive relationship, hence, the model is valid.

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