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Risk Assessment of an Accelerated Project to find the Optimal Risk Point for Crashing

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Abstract: The construction industry is diverse as it contains contractors, consultants, designers, owners, and others. Most of the construction projects were initiated on proposed date and were executed as per plan but over a certain period the projects above 70% completion stage were accelerated in order to avoid time over run. During the acceleration of projects, the construction is completed on time by being subjected to application of surplus amount of resources. The current study deals with the analysis of the factors impacted by cost during a project crashing using a questionnaire survey and the process of crashing a project through a crashing model. A crashing model is designed and configured to simulate crashing of a generated scenario using MS Excel. Time-cost trade off curve is plotted to obtain the optimum project duration. Finally, risk assessment is carried out for the simulated scenario in order to determine the optimum crashing level at minimum risk.

Keywords— Crashing model, Duration, Risk assessment, Schedule acceleration, Time-Cost trade-off

I. INTRODUCTION

Time management is important in any construction project. Without proper time management, many problems will occur such as extension of time or time overrun. Some of the researchers describe time overrun as delay and some of them describe that the time overrun is an effect from the construction delay time overrun became the most general problem in the construction industry worldwide. Delay or time overrun will affect all parties involved in the project. Hence, effective time management is very important and crucial to achieve successful completion of construction project.

Time is money especially on engineering and construction projects. Because delays in the completion of the project usually results in increased owner, engineer, contractor costs. The overall time of completing a project is vital to the financial success of the project. The desire to minimize costs and the time of performance often causes the occurrence of acceleration.

Calculating the acceleration cost of a construction project is not simply related to the direct and indirect cost of the project [4]. Working under pressure creates an environment that increases the chance of mistakes and redoing that work. Accelerating a project implies more work on a critical path and reducing project float time.

A. Need for the study

This study is needed for the following

- To find the optimal method to accelerate a construction project
- To find the risks involved in accelerating a construction project

B. Objective of the study

The main objective of this study is to analyse the risk involved in accelerating a construction project and finding the optimum risk point. In order to achieve this objective the following course of actions are necessary

- Establish a model for finding the cost for acceleration of a project
- Create a scenario of a project and simulate schedule acceleration and risk assessment

II. LITERATURE STUDY

Various literatures were analysed and the following inferences have been summarized.

- The advantages of increasing the pace of work by working under schedule acceleration can be offset by losses in productivity and quality [5].
- Acceleration of works rather than extending the project contract period can be done in case of delay [8].
- The efficiency of a project as determined from the project management is through its steering process [9].
- Scheduled acceleration of repetitive construction projects are based on cost slope and contractors' judgment [10].

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- Fast tracking of construction projects has impact on quality, profits, wastage of resource etc.[11]
- A comprehensive management information system (MIS) for schedule delay analysis is needed for schedule delay management and activity acceleration [7].
- The calculation of costs associated with extended duration or acceleration is quite straightforward [12].
- Overlapping activities was one of the most applied strategies to accelerate a project [6].

III. METHODOLOGY

The methodology flowchart shown in Figure A is utilized for achieving the objectives of the current study.

A. Impact Assessment

Impact assessment is carried out through a questionnaire survey by correlating the views of various respondents on the various factors considered [1]. The collected data is then analysed through SPSS [2], a software for statistical analysis, and the RII value among the considered factors is established. From the RII the parameters are ranked accordingly and the parameter which is most influenced by project scheduled acceleration is found.

A. Cost and Risk Assessment

A prototype model for finding the cost of crashing an activity and the risk associated with it is created in MS Excel. A general scenario of a construction work is taken and the data is entered in MS Project. The scenario is run through the model created in MS Excel. Cost and risk at various levels of crashing are analysed [3]. The model is then tuned to crash any set of activities from the results arrived.

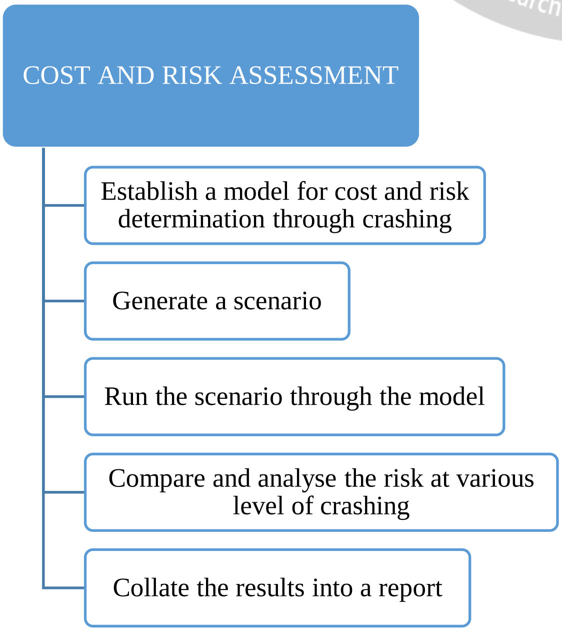

Figure-A Methodology flowchart

IV. GENERATION OF A SCENARIO FOR CRASHING

A scenario for project crashing is identified and scheduled using MS project. The details necessary for crashing the project is calculated and compiled for feeding into the crashing model.

A. Project brief description

The PWD board had decided the restoration of the Paruthipetpattu Lake, which was improperly maintained and was allowed to be polluted. People commonly call Paruthipetpattu Lake as Avadi Lake.

Avadi Lake lies right behind the Tamil Nadu Housing Board (TNHB) and Thirumullaivoyal. This lake has never dried up in many years. The people use it as a source of water for cultivation of farm lands long before. The water body attracts many birds during various seasons.

However, in recent decades it has lost most of its area to indiscriminate building and encroachment. There are some major problems at present, since the water of the monsoon showers moves inside of the buildings as they are in the area of the lake.

The proceedings for tender had been initiated in the early 2015 for a total estimated cost of 28 crores. Two companies P.S.T. Engineering Construction and Jammal Constructions won the tender as a joint contract

B. Project Details

Name of Work : "Eco-Restoration of Paruthipattu Lake, Avadi in Thiruvallur District"
Estimated Amount : Rs. 2100.00 Lakh
Client : TN Urban Infrastructure and Financial Service Ltd. (TNUIFSL)
Consultant : Infrastructure Management and Advisory Services Pvt. Ltd. (IMMAS)
Structural Design Consultant : Surya Prabha Structural
Name of Contractor : M/s.P.S.T. Engineering Construction
Quoted Amount : ₹ 18,63,33,645.00
Duration of work : 2 years (2017-2018)

C. Crashing Scenario

The embankment is the most critical component of the entire project and it takes the highest construction time as well. Thus, the construction of this component is a suitable scenario to crash using the crashing model.

The embankment acts as a bund to check water spillage from the lakeside to the park area as well as a pathway along which the visitors can walk alongside the lake. The bund also has drainage pipes and sluice gates to regulate water level in the lake.

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Total Length of the Embankment : 300 m
Height of Embankment : 3-4.2 m
Width of Embankment : 3.6 m
Total cost of work : ₹ 47,28,450.00
Construction Started on : Mar-2018
Construction Finished on : June-2018

D. Data for crashing

From the MS Project tool the necessary data required for the crashing model is extracted and tabulated in Table A and B. These data when fed into the model will crash the listed activities and give the optimal project cost with a time-cost trade off graph.

Table-A Activity details of scenario for crashing

Activity Code	Activity Name	Duration (days)	Predecessors
A	Stockpiling resources	15	
B	Preparing Foundation	30	
C	Laying core material	15	A,B
D	Laying Filler material	15	C
E	Laying Outer armor	10	D
F	Construction of spillway	5	D
G	Levelling of Surface	10	E,F
H	Waterworks/ plumbing	3	G
I	Brickwork	5	G
J	Woodwork	5	I
K	Plastering	10	I
L	Tile laying	3	H,K
M	Painting	5	K
N	Electrical wiring	4	J
O	Fitting accessories	2	L,M,N
P	Final finishing work	2	O

Table-B Scenario details for cost slope calculation

Activity Code	Normal cost (₹)	Crash cost (₹)	Normal Duration (days)	Crash Duration (days)
A	86,250	86,250	15	15
B	7,21,500	7,21,500	30	30
C	16,38,750	16,46,500	15	10
D	9,63,750	9,71,500	15	10
E	2,94,000	3,14,400	10	7
F	95,250	95,250	5	4
G	2,95,500	3,10,350	10	7
H	39,900	39,900	3	3
I	99,250	1,01,100	5	4
J	82,250	82,250	5	5
K	1,56,000	1,56,000	10	10
L	1,08,500	1,08,500	3	3
M	46,250	46,250	5	5
N	48,300	48,300	4	4
O	31,300	32,550	2	1
P	21,700	21,700	2	2

V. THE CRASHING OPERATION

The data compiled from MS Project is fed into the designed crashing model to crash and accelerate the project activities. Table C shows how the data is entered into the model.

Table-C Activity details in crashing model

	A	B	C	D
1 2	**Activity**	**Immediate Predecessor**	**Duration (Days)**	**Cost (Rs.)**
3	A		15	₹ 86,250.00
4	B		30	₹ 7,21,500.00
5	C	A,B	15	₹ 16,38,750.00
6	D	C	15	₹ 9,63,750.00
7	E	D	10	₹ 2,94,000.00
8	F	D	5	₹ 95,250.00
9	G	E,F	10	₹ 2,95,500.00
10	H	G	3	₹ 39,900.00
11	I	G	5	₹ 99,250.00
12	J	I	5	₹ 82,250.00
13	K	I	10	₹ 1,56,000.00
14	L	H,K	3	₹ 1,08,500.00
15	M	K	5	₹ 46,250.00
16	N	J	4	₹ 48,300.00
17	O	L,M,N	2	₹ 31,300.00
18	P	O	2	₹ 21,700.00
19			**Total**	**₹ 47,28,450.00**

A. Step-I Critical path calculation

Calculate the critical path from the successor-predecessor relationship between the activities fed into the model shown in Table D. The total duration of the available paths with higher activity time is calculated as shown in Table E. Table F displays the calculated critical path from the list of available paths.

Table-D Successor-Predecessor relationship

	F	G	H	I
1 2	**Activity**	**Immediate Predecessor(s)**	**Immediate Successor(s)**	
3	A		C	E

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4	B		C	
5	C	A,B	D	
6	D	C	E	F
7	E	D	G	
8	F	D	G	
9	G	E,F	H	I
10	H	G	L	
11	I	G	J	K
12	J	I	N	
13	K	I	L	M
14	L	H,K	O	
15	M	K	O	
16	N	J	O	
17	O	L,M,N	P	
18	P	O		

Table-E Duration of available path

	A	B	C	D	E	F	G	H	I	J	K	L
37 38	**Total duration of each path**											**Output**
39	**BCDEGHLOP**	**30**	**15**	**15**	**10**	**10**	**3**	**3**	**2**	**2**	**0**	**90**
40	**BCDEGIJNOP**	**30**	**15**	**15**	**10**	**10**	**5**	**5**	**4**	**2**	**2**	**98**
41	**BCDEGIKLOP**	**30**	**15**	**15**	**10**	**10**	**5**	**10**	**3**	**2**	**2**	**102**
42	**BCDEGIKMOP**	**30**	**15**	**15**	**10**	**10**	**5**	**10**	**5**	**2**	**2**	**104**
43	**BCDFGIKMOP**	**30**	**15**	**15**	**5**	**10**	**5**	**10**	**5**	**2**	**2**	**99**

Table-F Calculated critical path

	A	B	C	D
45	**Critical path**		**BCDEGIKMOP**	

B. Step-II Cost slope calculation

The normal cost, normal duration, crash cost and crash time calculated with the data taken from MS Project is fed into the crashing model as shown in Table G.

Table-G Cost slope for crashing

	K	L	M	N	O	P
1 2	**Activity**	**Normal Time (Days)**	**Crash Time (Days)**	**Normal Cost (Rs.)**	**Crash Cost (Rs.)**	**Cost Slope (Rs.)**
3	A	15	15	86250	86250	**0**
4	B	30	30	721500	721500	**0**
5	C	15	10	1638750	1646500	**1550**
6	D	15	10	963750	971500	**1550**
7	E	10	7	294000	314400	**6800**
8	F	5	4	95250	95250	**0**
9	G	10	10	295500	310350	**0**
10	H	3	3	39900	39900	**0**
11	I	5	4	99250	101100	**1850**
12	J	5	5	82250	82250	**0**
13	K	10	10	156000	156000	**0**
14	L	3	3	108500	108500	**0**
15	M	5	5	46250	46250	**0**
16	N	4	4	48300	48300	**0**
17	O	2	1	31300	32550	**1250**
18	P	2	2	21700	21700	**0**

The data entered into the crashing model calculates the cost slope for each activity that could be crashed. Negative values indicate the fed data is incorrect. Zero cost slope indicate activity cannot be crashed.

C. Step-III Crashing of activities

The final step of the crashing model is to crash the activities based on the data fed into it. This process requires simulating the data into various formulas and codes through numerous iterations. This step is the most tedious work to be done by the model and erroneous data may complicate or even void the results.

The model is configured to simulate the crashing process fifteen times, as the scenario taken for study can only be crashed for that specific amount of times. The indirect cost of the project formulated from the resources and activities is fed into the crashing model to calculate the total cost of the project as shown in Table H. Depending on this cost, the crashing iterations required to attain optimum crash time will vary.

Table-H Calculation of total cost

	U	V
1	Direct cost (Rs.)	**₹ 47,28,450.00**
2	Indirect cost (Rs.)	3000
3	Total cost (Rs.)	**₹ 50,34,450.00**

Table-I Crashing Chart

	X	Y	X	AA	AB	AC
1 2	**Crash count**	**Critical path**	**Critical activity to crash**	**Crash duration (days)**	**New Total Duration (days)**	**New total cost (Rs.)**
3	**1**	**BCDEGIKMO**	**O**	**1**	**103**	**503870**

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		P				0
4	2	BCDEGIKMOP	C	14	102	5037250
5	3	BCDEGIKMOP	C	13	101	5035800
6	4	BCDEGIKMOP	C	12	100	5034350
7	5	BCDEGIKMOP	C	11	99	5032900
8	6	BCDEGIKMOP	C	10	98	5031450
9	7	BCDEGIKMOP	D	14	97	5030000
10	8	BCDEGIKMOP	D	13	96	5028550
11	9	BCDEGIKMOP	D	12	95	5027100
12	10	BCDEGIKMOP	D	11	94	5025650
13	11	BCDEGIKMOP	D	10	93	5024200
14	12	BCDEGIKMOP	I	4	92	5023050
15	13	BCDEGIKMOP	E	9	91	5026850
16	14	BCDEGIKMOP	E	8	90	5030650
17	15	BCDEGIKMOP	E	7	89	5034450

Table I clearly portrays the full functionality of the crashing model in crashing an activity form the critical path. A new total cost is calculated from the crashed duration every time an activity is crashed. The optimum duration to which the project can be crashed is found from the now calculated total cost.

D. Step-IV Time-Cost Trade Off Curve

Time-cost trade off curve is a graph between the crashed project duration and the new total cost for each crashing. Figure B displays the trade-off curve from which the optimum project duration can be interpreted.

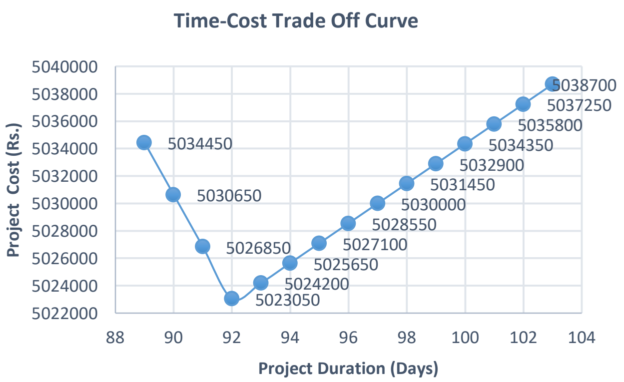

Figure-B Time-cost trade off curve

The optimum project duration will have the least project cost. Thus for the considered scenario,

Construction of Embankment

Project cost : ₹ 50,23,050.00

Project duration : 92 Days

However, this duration does not factor in the risks involved during crashing. Thus, risk assessment is required in order to determine the best crash time and project cost.

VI. Risk Assessment

Risk assessment is carried out to with the following assumptions

- Risk percentage increases linearly with each crashing
- Risk is maximum for a project crashed to its limit
- Risk in null for a project prior to crashing

For proper risk assessment, a standard risk-rating matrix is required. Thus a risk rating matrix is defined in Table J to be used for risk assessment.

Table-J Redefined risk rating matrix

	LIKELIHOOD				
IMPACT	**Rare**	**Unlikely**	**Possible**	**Likely**	**Almost certain**
Catastrophic	5	10	15	20	25
Major	4	8	12	16	20
Moderate	3	6	9	12	15
Minor	2	4	6	8	10
Insignificant	1	2	3	4	5

A. Establishing Risk Level

From the ranking of seven major factors taken from previous study [1], it can be noted that a higher level of focus is given to some factors while some are mostly neglected. This will lead to higher risk when the project is accelerated. The factors that were not given proper weightage and were neglected will lead to the project's failure. Hence, a risk level is assigned to each factor based on their ranking. The level of risk of the factors considered are shown in Table K.

Table-K Factors-risk level

S.no.	Main Factor	Level of risk
1	Organization	Insignificant
2	Manpower	Minor
3	Equipment	Low
4	Construction	Moderate
5	Material	High
6	Quality	Major

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7	Safety	Catastrophic

The risk level assigned to each factor denotes the impact on the project that may be caused when an incident occurs due to the factor involved. However, the likelihood for such incidents to occur will vary. Thus, a relationship between impact and likelihood of risks between the factors is necessary.

Risk is categorized based on the seven factors considered in Table K and the risk rating matrix shown in Table J. Table L shows the risk rating calculated based on the assumptions made.

Table-L Risk rating calculation

Crash count	New Total Duration (days)	New total cost (Rs.)	Risk level rating
1	103	5038700	7%
2	102	5037250	13%
3	101	5035800	20%
4	100	5034350	27%
5	99	5032900	33%
6	98	5031450	40%
7	97	5030000	47%
8	96	5028550	53%
9	95	5027100	60%
10	94	5025650	67%
11	93	5024200	73%
12	92	5023050	80%
13	91	5026850	87%
14	90	5030650	93%
15	89	5034450	100%

The optimum project durations through crashing is 92 days but its corresponding risk level is 80%. This implies the chance that the project could encounter an incident that delays it is very likely to occur.

This risk rating for the supposed optimum project duration can be further broken down based on the seven factors considered as shown in Figure C.

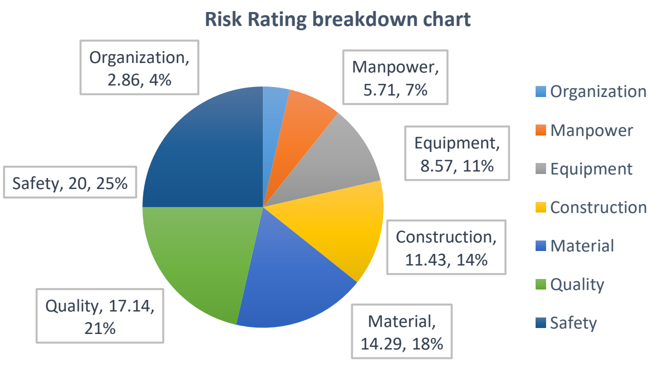

Figure-C Risk breakdown chart for 92 days duration

From Figure C it could be observed that for 92-day duration the 80% risk is majorly contributed by incidents in safety followed by defect in quality. Table M and N gives a more through breakdown of the risk rating level.

Table-M Risk Rating analysis

Main Factor	Risk Rating Level					
	92 days	93 days	94 days	95 days	96 days	97 days
	80%	73%	67%	60%	53%	47%
Organization	2.86	2.61	2.39	2.14	1.89	1.68
Manpower	5.71	5.21	4.79	4.29	3.79	3.36
Equipment	8.57	7.82	7.18	6.43	5.68	5.04
Construction	11.43	10.43	9.57	8.57	7.57	6.71
Material	14.29	13.04	11.96	10.71	9.46	8.39
Quality	17.14	15.64	14.36	12.86	11.36	10.07
Safety	20	18	17	15	13	12

Table-N Risk Rating analysis for 92 days duration

Factors	Risk rating	Impact Level	Likelihood to occur
Safety	20	Catastrophic	Likely
		Major	Almost certain
Quality	17.14	Major	Likely
Material	14.29	Catastrophic	Possible
		Moderate	Almost certain
Construction	11.43	Major	Possible
		Moderate	Likely
Equipment	8.57	Major	Unlikely
		Minor	Likely
Manpower	5.71	Catastrophic	Rare
		Insignificant	Almost certain
Organization	2.86	Moderate	Rare
		Insignificant	Possible

A through risk analysis for the crashed duration prior to the supposed optimum project duration is done and tabulated in Table M.

In order to find the optimum risk point an optimum risk curve consisting of the time-cost trade off curve and risk rating level is plotted as shown in Figure D.

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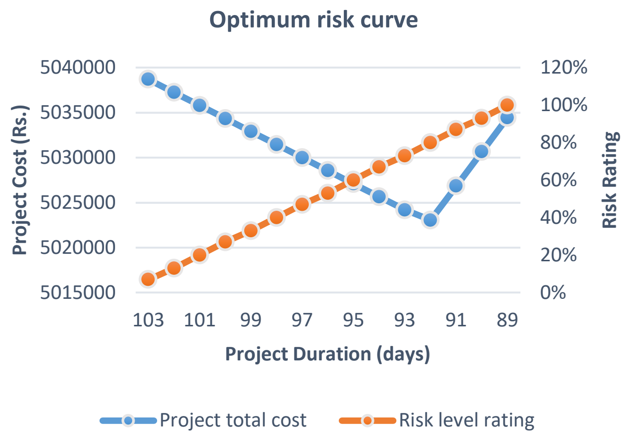

Figure-D Curve for optimum risk level

From Figure D the optimum risk point is 60% risk level at 95 days project crashing. Thus the new optimum level of crashing for the considered scenario is

Construction of Embankment

Project cost : ₹ 50,27,100.00

Project duration : 95 Days

Thus, the project is crashed optimally at minimum risk without compromising the cost associated with it. A through risk rating analysis for 95-day duration is given in Table O.

Table-O Risk Rating analysis for 95 days duration

Factors	Risk rating	Impact Level	Likelihood to occur
Safety	15.00	Catastrophic	Possible
		Moderate	Almost certain
Quality	12.86	Major	Possible
		Moderate	Likely
Material	10.71	Catastrophic	Unlikely
		Minor	Almost certain
Construction	8.57	Major	Unlikely
		Moderate	Possible
		Minor	Likely
Equipment	6.43	Moderate	Unlikely
		Minor	Possible
Manpower	4.29	Major	Rare
		Minor	Unlikely
		Insignificant	Likely
Organization	2.14	Minor	Rare
		Insignificant	Unlikely

VII. CONCLUSION

A study on cost and its impact during a project acceleration while maintaining the risk at minimum levels was carried out. All objectives and sub objectives considered for the study were met and the project was concluded with a brief summary of its findings.

A. Findings

- Questionnaire survey concluded that among the considered factors safety was given the least importance and thus was more prone to risk.
- Time-cost Trade off curve formed between the project cost and durations crashed at several stages did not factor in the risk involved during project acceleration.
- Risk assessment revealed that crashing the considered scenario to its optimum duration greatly increased the risk upto 80%.
- By adding risk-rating values to the time-cost trade off curve, a curve known as the optimum risk curve was plotted and optimum risk point was obtained.
- The point before the optimum risk point will have higher project costs at lower risk and the point beyond the optimum risk point gave lower project costs but higher risk.

This thesis detailed the various factors that had impact on cost, which could occur during project acceleration, and related risk ratings were given to these factors according to their ranking found through a questionnaire survey.

A model for crashing a project had been designed and configured using MS Excel. This model was used to crash a generated scenario of an Embankment construction that had an estimated duration of 104 days. The model was simulated to crash the project 15 times and a Time-Cost trade off curve had been prepared with the data obtained as shown in Figure E.

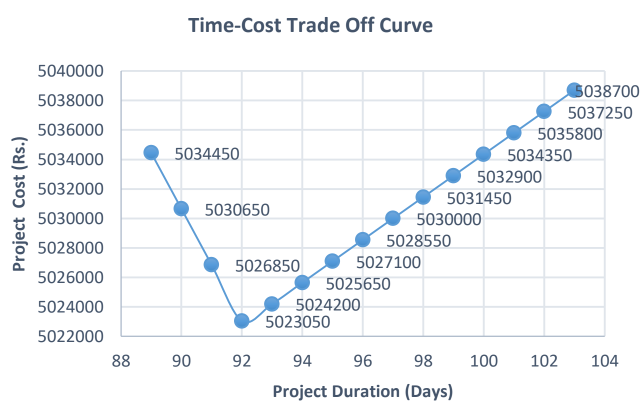

Figure-E Time-cost trade off curve

The optimum duration obtained from the curve did not factor in the risk involved during crashing, thus risk assessment for the considered crashing simulation was

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carried out. The risk rating levels for each factor considered at various levels of crashing were determined as shown in Table P

Table-P Risk Rating analysis

Main Factor	Risk Rating Level					
	92 days	93 days	94 days	95 days	96 days	97 days
	80%	73%	67%	60%	53%	47%
Organization	2.86	2.61	2.39	2.14	1.89	1.68
Manpower	5.71	5.21	4.79	4.29	3.79	3.36
Equipment	8.57	7.82	7.18	6.43	5.68	5.04
Construction	11.43	10.43	9.57	8.57	7.57	6.71
Material	14.29	13.04	11.96	10.71	9.46	8.39
Quality	17.14	15.64	14.36	12.86	11.36	10.07
Safety	20	18	17	15	13	12

Using the obtained data an optimum risk curve was plotted as shown in Figure F

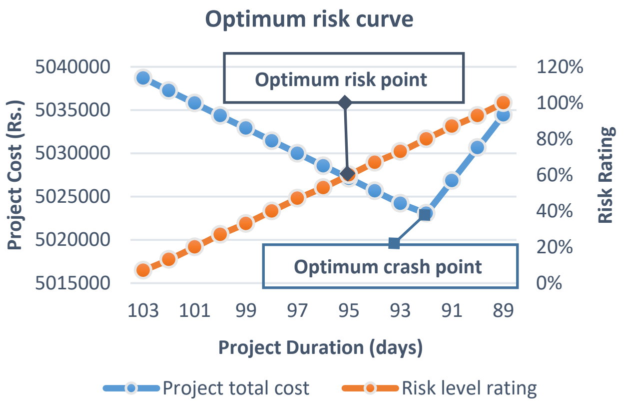

Figure-F Curve for optimum risk level

From the curve, the optimum risk point was found and the optimum crashing duration was calculated without compromising project cost. On comparing cost between optimal crash point and optimal risk point, it is increased by Rs. 4050, which is 0.08% more than the optimal crash point. When the project is crashed to its limit, the cost is increased by 7350 Rs, which is 0.15% higher from the optimal risk point, and Rs. 11400 Rs., which is 0.22% higher than the optimal crash point.

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