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Risk and Cost Implications of Project Schedule Crashing

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ABSTRACT: Delay in project schedule is a common issue in construction industry. Considerable percentage of projects are falling behind the schedule causing damage to almost every involved party. In this thesis, schedule crashing for compensating delay and reducing the duration of project have been studied. A framework is developed for the process of crashing and quantitative risk evaluation. Framework consist of two parts, in first part linear programming approach is used for the formulation of crashing problem and it is solved using excel solver. In second part probabilistic Quantitative risk evaluation of schedule after crashing is done with the aid of @RISK7.5. An example of crashing is solved using the developed framework which shows that the optimum crashed duration of an undertaken project is 51 days at which the total project cost is minimum and it is also seen that the project duration can further reduce to 49 days but at this duration total project cost is not minimum. After 49 days crashing is not possible. Then quantitative risk evaluation is done and it is found that initial probability of project completion is more than that after crashing which shows that after crashing the project we get desired completion date but the risk of completing project on time is increased..

KEYWORDS: Crashing, Linear Programming, Risk Evaluation, Solver, Framework, Probabilistic.

I. INTRODUCTION

As per IS 15883 (Part 2), the word "PROJECT" in construction field generally refers to a nonrecurring endeavor undertaken that create a facility or service. Every project has certain objectives and those objectives cannot be attained unless the activities associated with them are managed properly

But it has been seen that even after proper scheduling & appointing experienced professionals to execute the project, its stipulated time and cost, are getting delayed due to various problems like unavailability of resource at the time of execution, lack of co-ordination, strikes, rework, poor organization, material shortage, equipment failure, natural calamities etc.

Basically, Time and cost are the two main parameters of a construction project and both are interrelated. Whenever the project slips from schedule the cost associated with it will get increase. To meet the needs of both contractor and client the project should be completed within stipulated time with an optimum cost. So whenever there is a slip from the actual plan then schedule crashing procedure is adopted to keep the project in track. Crashing of the project schedule refers to accelerating or shortening the duration of project activities in order to complete the project sooner.

Now a day most of the construction projects are running out of time so an effective and meaningful study is needed to understand the process of schedule crashing and its cost implications, also to get aware of the risk associated with it.

II. LITERATURE SURVEY

Jen, H. and Chen, Y.C. (2009).. developed an analytical model by first using Particle swarm optimization heuristic algorithm to find the minimum project costs under time constraint. MCS is then implemented to build a completion probability table of time/cost combinations. The time and cost from PSO method is compared with the probability matrix. An analysis is provided as a demonstration.

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Wakas.S.Khalaf et al. (2010) developed a framework for the approach of stretching noncritical activities to complete the project in shortest possible duration at least cost within available maximum budgeting and they achieved this by crashing all activities simultaneously in the project network then used Linear Programming (LP) technique to build a model to maximize the savings that will yield from stretching noncritical activities.

Omar M. Elmabrouk(2012) reviewed ideas of linear programming and critical path methodology to explain recent modeling structures that are of great worth in analyzing extended planning horizon project time-cost crashes issues. A simplified illustration of a small project and a linear programming model was developed to represent this method. Procedures to resolve these numerous issues formulations were cited and also the Holcaust was obtained by using LINDO program.

Rana Ali Al haj (2012). has developed a new time-cost optimization framework that may offer an optimum costtime value for a project taking into consideration the result of float loss and presents 2 new frameworks for resolution the time-cost optimization problem taking under consideration the float loss impact “a random framework and a nonlinear integer Programming (NLIP) framework”. The random framework uses Monte Carlo Simulation (MCS) to calculate the effect of float loss on risk. this can be later translated into an extra cost to the improvement problem. The Non-Linear integer Programming (NLIP) framework uses What’s Best solver to search out an efficient solution to the optimisation problem whereas incorporating the float loss value calculated in line with the float goods approach

Kunpeng Li, K., Shao, B. and Zebst, P., (2012). Introduces a new and efficient AON-Solver approach to solve project crashing issues. The new approach uses conventional critical path ideas to work out the project completion time and to define network structures in stand out For better understanding the cost-time tradeoffs in project flaming.

Najib, Fredric Ibrahim and Daniel Hayek (2012)reports that crashing a schedule has proved to be a time consuming manual task and susceptible to errors. They programmed an algorithm of crashing in JavaScript along with a user friendly web interface and then crashed manually an example of a new project and another for an ongoing project and by the software, and compared the results .

Nafish Sarwar Islam(2013) has studied the stochastic nature of activity time and developed an algorithm for optimum crashing method to minimize the required cost while attaining a specified completion time.

Vikas Pawar et al. (2014) identified and assessed various risks in case of fast track projectsand repots that evaluation of risks can help in prioritizing risks for effective risk management and successful completion of a project

Pratik Ganame, Pravin Chaudhari (2015) studied the qualitative and qualitative analysis. Qualitative analysis is done by probability impact (PI) matrix and quantitative analysis is done by Monte Carlo simulation.@RISK by Palisade corp.

Katti, A. and Darade, M. (2016) has developed a framework for reducing total project time at the least added total cost by crashing the duration of an actual residential building construction project. The project is scheduled in Microsoft Project and crashed using the Solver add-in of Microsoft Excel.

S. K. Biswas,C. L. Karmaker,T. K. Biswas (2016) performed regression analysis to identify the relationship between the times and costs .They formulize an optimization problem modelwhich is solved by the aid of MATLAB.

Syed Burhanuddin Hilmi Syed Mohamad et al. reports that labour productivity decline with the use of crashing approach and it will give an impact to the quality of work at construction site.

III. SCHEDULE CRASHING AND RISK EVALUATION

In The Following Project (Adopted From Construction Management By Dr. Emad Elbeltagi) The Contractor Wants To Reduce The Duration To 51 Days With Minimum Increase In Total Cost Of The Project , Durations And Direct Costs For Each Activity In The Network Are Given In The Table 4.1. Determine The Minimum Total Project Cost, Assuming The Indirect Cost Is 12500 Rs/Day.

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Vol. 7, Issue 5, May 2018

Table 1 : Cost-Time slope of the activities

ACTIVITY	PRECEDED BY	NORMAL		CRASH	
		DURATION	COST(in 100 RS)	DURATION	COST(in 100 RS)
A	-	12	7000	10	7200
B	A	8	5000	6	5300
C	A	15	4000	12	4600
D	B	23	5000	23	5000
E	B	5	1000	4	1050
F	C	5	3000	4	3300
G	E,C	20	6000	15	6300
H	F	13	2500	11	2580
I	D,G,H	12	3000	10	315

Table 2 : Cost-Time slope of the activities

ACTIVITY	CRASHED TIME (1)	ADDITIONAL COST (2)	COST SLOPE (2)/(1)
A	12-10=2	7200-7000=200	100
B	8-6=2	5300-5000=300	150
C	15-12=3	4600-4000=600	200
D	23-23=0	5000-5000=0	0
E	5-4=1	1050-1000=50	50
F	5-4=1	3300-3000=300	300
G	20-15=5	6300-6000=300	60
H	13-11=2	2580-2500=80	40
I	12-10=2	3150-3000=150	75

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Vol. 7, Issue 5, May 2018

We can identify the critical path of the project to determine the project's expected completion time. Based on the calculation given in Table 4.3. The project will be completed within 59 days and critical path is A-C-G-I.

Table 3 : Critical path

ACTIVITY	DURATION	EST	EFT	LST	LFT	SLACK
A	12	0	12	0	12	0
B	8	12	20	14	22	2
C	15	12	27	12	27	0
D	23	20	43	24	47	4
E	5	20	25	22	27	2
F	5	27	32	29	34	2
G	20	27	47	27	47	0
H	13	32	45	34	47	2
I	12	47	59	47	59	0

There is restriction for the extent of project crash time, Model will provide feasible result if only adjusted deadline of the project is greater than or equal to 47 days.

Linear programming model

Defining the variables:

Let, X_A = Time when activity A is finished.

X_B = Time when activity B is finished.

X_C = Time when activity C is finished..

X_D = Time when activity D is finished.

X_E = Time when activity E is finished.

X_F = Time when activity F is finished.

X_G = Time when activity G is finished.

X_H = Time when activity H is finished.

X_I = Time when activity I is finished.

Y_A = Number of days activity A will be crashed.

Y_B = Number of days activity B will be crashed.

Y_C = Number of days activity C will be crashed.

Y_D = Number of days activity D will be crashed.

Y_E = Number of days activity E will be crashed.

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Vol. 7, Issue 5, May 2018

Y_F = Number of days activity F will be crashed.

Y_G = Number of days activity G will be crashed.

Y_H = Number of days activity H will be crashed.

Y_I = Number of days activity I will be crashed.

Objective Function

$$\text{Minimize } Z = 100Y_A + 150Y_B + 200Y_C + 0Y_D + 50Y_E + 300Y_F + 60Y_G + 40Y_H + 75Y_I + X_9 * 125 \quad (1)$$

Constraints of the model

Crash time constraint:

$$Y_A \leq 2 \quad (2)$$

$$Y_B \leq 2 \quad (3)$$

$$Y_C \leq 3 \quad (4)$$

$$Y_D \leq 0 \quad (5)$$

$$Y_E \leq 1 \quad (6)$$

$$Y_F \leq 1 \quad (7)$$

$$Y_G \leq 5 \quad (8)$$

$$Y_H \leq 2 \quad (9)$$

Constraints unfolding the Network:

$$X_{START} = 0, \quad (10)$$

$$X_A \geq X_{START} + 12 - Y_A \quad (11)$$

$$X_B \geq X_A + 12 - Y_B \quad (12)$$

$$X_C \geq X_A + 12 - Y_C \quad (13)$$

$$X_D \geq X_B + 12 - Y_D \quad (14)$$

$$X_E \geq X_B + 12 - Y_E \quad (15)$$

$$X_F \geq X_C + 12 - Y_F \quad (16)$$

$$X_G \geq X_C + 12 - Y_G \quad (17)$$

$$X_G \geq X_E + 12 - Y_G \quad (18)$$

$$X_H \geq X_F + 12 - Y_H \quad (19)$$

$$X_I \geq X_D + 12 - Y_I \quad (20)$$

$$X_I \geq X_G + 12 - Y_I \quad (21)$$

$$X_I \geq X_H + 12 - Y_I \quad (22)$$

Project completion constraints:

$$X_I \leq 59 \quad (23)$$

And, $X_{START}, X_A, X_B, X_C, X_D, X_E, X_F, X_G, X_H, X_I, Y_A, Y_B, Y_C, Y_D, Y_E, Y_F, Y_G, Y_H, Y_I \geq 0$.

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Vol. 7, Issue 5, May 2018

Solution of the model using Excel Solver.

We have defined the objective function and all the constraints for the problem stated in Kungpeng li et al.(2012). To obtain the minimum crash cost we have to minimise the objective function. We can find the solution for the model with the help of Excel Solver. For the solution of Linear Programming model using Excel Solver. Enter the objective function and constraints as shown in the Figure 1.

	XA	XB	XC	XD	XE	XF	XG	XH	XI	YA	YB	YC	YD	YE	YF	YG	YH	YI	TOTAL	SIGN	RHS	
VALUES	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OBJECTIVE	0	0	0	0	0	0	0	0	0	100	150	200	0	50	300	60	40	75	0	<	2	
CONS-1										1									0	<	2	
CONS-2											1								0	<	2	
CONS-3												1							0	<	3	
CONS-4													1						0	<	0	
CONS-5														1					0	<	1	
CONS-6															1				0	<	1	
CONS-7																1			0	<	5	
CONS-8																	1		0	<	2	
CONS-9																		1	0	<	2	
CONS-10	1										1								0	>	12	
CONS-11	-1	1										1							0	>	8	
CONS-12	-1		1										1						0	>	15	
CONS-13		-1		1										1					0	>	23	
CONS-14		-1			1										1				0	>	5	
CONS-15			-1			1										1			0	>	5	
CONS-16					-1		1										1		0	>	20	
CONS-17				-1				1										1	0	>	20	
CONS-18						-1		1											0	>	13	
CONS-19				-1					1										0	>	12	
CONS-20							-1		1									1	0	>	12	
CONS-21								-1	1										0	>	12	
CONS-22									1										0	<	59	
CONS-23										1									0	>	0	
CONS-24	1																		0	>	0	
CONS-25		1																	0	>	0	
CONS-26			1																0	>	0	
CONS-27				1															0	>	0	
CONS-28					1														0	>	0	
CONS-29						1													0	>	0	
CONS-30							1												0	>	0	
CONS-31								1											0	>	0	
CONS-32									1										0	>	0	
CONS-33										1									0	>	0	
CONS-34											1								0	>	0	
CONS-35												1							0	>	0	
CONS-36													1						0	>	0	
CONS-37														1					0	>	0	
CONS-38															1				0	>	0	
CONS-39																1			0	>	0	
CONS-40																	1		0	>	0	
CONS-41																		1	0	>	0	

Figure1: LPP Model

The solution for the model is shown in Figure 1;

OBJECTIVE	FINAL VALUE
Z	43545
VARIABLE	FINAL VALUE
XA	10
XB	18
XC	25
XD	41
XE	23
XF	30
XG	41
XH	41
XI	51
YA	2
YB	0
YC	0
YD	0
YE	0
YF	0
YG	4
YH	2
YI	2

*Vale of z in hundred

Figure 1: Solution of the LP model using Solver

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Vol. 7, Issue 5, May 2018

So, the Activity A, G, H and I are required to be crashed by 2, 4, 2 & 2 Days respectively to get least increase in total cost and duration for project completion.

New total cost = Rs. 4354500

New Duration =51 days.

Evaluation of Risk.

Assumptions:

- Most likely time equals to normal duration.
 - Optimistic and Pessimistic time equals to 70 % & 125 % of normal duration.
 - For the purpose of distribution of time for an activity triangular distribution is used.
 - For the purpose of risk evaluation @RISK7.5 is used and its results are shown in Figures 4.5 and 4.6.
 - Except the sampled values all the values are approximated to its nearest integer values on the higher side.
- Assumption for triangular distribution of activity time is adopted from Pratik Ganame et al. (2015) and the process of risk evaluation is studied from the on demand webinar provided by the team of Palisade Corp.

ACTIVITY	DURATION	OPTIMISTIC	MOST LIKELY	PESSIMISTIC	SAMPLED	USING @RISK7.5 ANALYSIS
A	12	9	12	15	12	PROBABILITY OF COMPLETION
B	8	6	8	10	8	
C	15	11	15	19	15	59 DAYS
D	23	17	23	29	23	53.00%
E	5	4	5	7	5.33333333	
F	5	4	5	7	5.33333333	
G	20	14	20	25	19.66666667	
H	13	10	13	17	13.33333333	
I	12	9	12	15	12	
	59			DURATION	58.66666667	

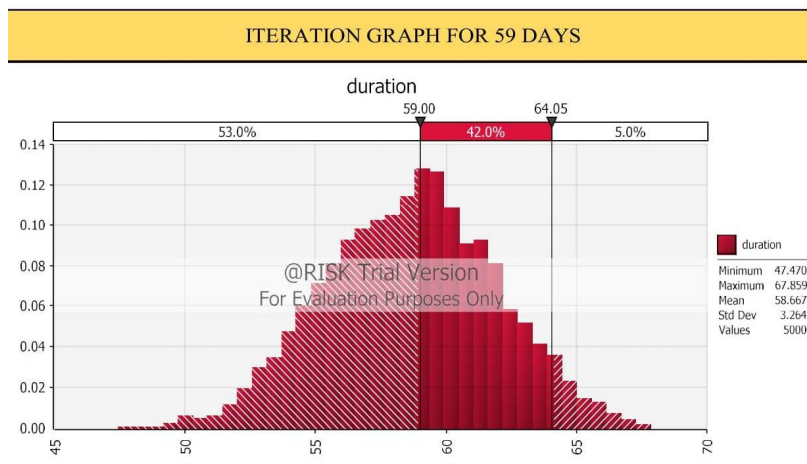


Figure 2 : Graph for 59 days project duration.

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Vol. 7, Issue 5, May 2018

ACTIVITY	DURATION	OPTIMISTIC	MOST LIKELY	PESSIMISTIC	SAMPLED	USING @RISK7.5 ANALYSIS
A	10	9	10	13	10.66666667	PROBABILITY OF COMPLETION
B	8	6	8	10	8	
C	15	11	15	19	15	51 DAYS
D	23	17	23	29	23	31.10%
E	5	4	5	7	5.333333333	
F	5	4	5	7	5.333333333	
G	16	12	16	20	16	
H	11	10	11	17	12.66666667	
I	10	9	10	13	10.66666667	
	51			DURATION	52.33333333	

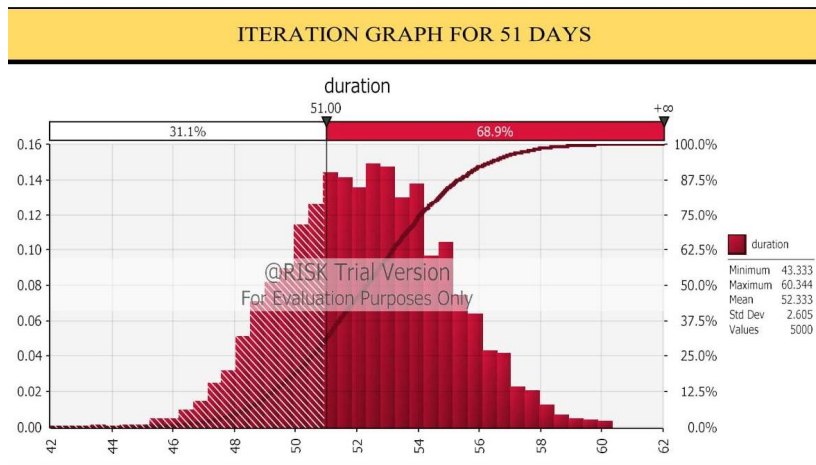


Figure 3 : Graph for 51 days project duration.

IV. EXPERIMENTAL RESULTS

DURATION	DIRECT COST(RS)	INDIRECT COST(RS)	TOTAL COST(RS)	PROBABILITY OF COMPLETION
51 DAYS	3717000	637500	4354500	31.10%
59 DAYS	3650000	737500	4387500	53.00%

Table 4 : Duration, cost and probability

V. CONCLUSION

- While project crashing is opted for reducing its duration, its direct cost increased, whereas indirect cost decreases.
- Project crashing involves the increase in risk of any project. As we have seen that in above example as we have crashed the schedule the probability of completion of project get reduced by 21.90%.
- If the project manager is aware of such increment in risk they can adopt suitable remedial measures which ultimately may lead to successful completion of project.

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Vol. 7, Issue 5, May 2018

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