Optimization of Activity Crashing by Linear Programming Model

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Abstract— In recent era of project management there is demand of completing project on time or in some cases before time. To meet the schedule deadline at minimum cost and effort is matter of importance. Present paper explains how to optimize activity crashing with the help of Solver in Microsoft Excel. In order to explain the scenario more effectively data of completed construction site has been used. Also an effort is made to reduce its actual duration by crashing its critical activity optimally to achieve required results with satisfying budget constrain. This paper may help any construction related person to use linear programming in excel and manage schedule and resources effectively.

Key words: Linear Programming, Construction Management, Activity Crashing, Scheduling, Delay Management

I. INTRODUCTION

Project management is procedure of planning, organizing, and controlling resources to achieve specific goals. It comprises of developing a project plan, which includes defining and confirming the project goals and objectives, identifying tasks. It also helps in, how goals will be achieved, quantifying the resources needed, and determining budgets including timelines for completion. A project is a temporary effort with a defined beginning and end (usually time constrained, and sometimes constrained by funding or deliverable resources), undertaken to meet unique goals and objectives. The basic challenge of project management is to achieve all of the project goals and objectives while satisfying the defined constraints. The primary constraints are scope, time, quality and budget. The secondary and more important challenge is to optimize the allocation of necessary inputs and integrate them to meet pre-defined objectives. A successful Project Manager must simultaneously manage the four basic elements of a project: resources, time, money, and most importantly, scope. All these elements are interconnected. Each must be managed effectively. All must be managed together for the success of project and project manager".

Project scheduling is allocation process of the available resources to the project activities to calculate the start time and finish time of each activity. If resources are sufficient but the demand varies dramatically over the life of the project, it may be desirable to adjust resource demand by delaying noncritical activities (using slack) to lower peak demand and thus, improving the resource utilization. This process is known as resource smoothing or leveling. On the other hand, if resources are not adequate to meet the highest demands, the late start of some of the activities must be delayed, and the duration of the project may be increased. This process is termed as resource constrained scheduling.

The project manager most of the time "is concerned to reduce the scheduled completion time of a project to meet the deadline" .Project duration can be reduced by assigning more labor to project activities, in terms of over time, and by assigning more number of deliverable resources. However, the additional labor and resources increase the project cost. So, the decision to reduce the project duration must be based on an analysis of the time- cost tradeoff (crashing). Project crashing is a method for minimizing the project duration by reducing the time of one or more of the critical project activities to less than its normal activity time. The purpose of crashing is to reduce project duration while minimizing the cost of crashing to meet the project deadline"

Linear programming can be used to generate one of the most popular optimization models for project scheduling (crashing). "Linear programming is a problem-solving approach developed to help managers make decisions. It is a powerful tool used by managers and planners to obtain optimal solutions to problems that involve constrains or limitations on their resources. These problems are referred to as constrained optimization problems". The linear programming model presented in this case will illustrate how Excel Solver can be used in project management time-cost trade off (crashing). It will help researcher or user to decide on how much to crash each activity so that the deadline of the project is met at a minimum cost.

II. LITERATURE SURVEY

Amol Sinh (1) studied multi-project scheduling problem with resource constrained situation and used hybrid algorithm to solve the problem. Mark et al. (2) formulated equations for project planning which uses a nonlinear optimization model for resource allocation. Qiao Jianfeng (3) used optimal control theory for safety risk assessment in case of over allocation. Cristina Selaru (4) compared different output by different pattern of resource allocation of real life business and provided best solution from her findings. Zee Woon Lee (5) examined effect of different resource allocation policies on project duration and developed policy which can reduce duration and simultaneously decrease uncertainty also. Dr Andy M. Connor (6) used three different metaheuristic search algorithms namely simulated annealing, tabu search and genetic algorithms for scheduling and resource allocation of construction project and found that all of these software based techniques are suitable but comparatively genetic algorithm is better than rest two. C. Chantrapornchai (7) discussed different aspects of developing project management software prototype for resource allocation and scheduling. Grzegorz Pawinski (8) used critical chain project management (CCPM) to obtain cheapest project schedule with respect to time constrains. Roel Leus (9) developed branch-and-bound algorithm to solve resource allocation problem and compared results with benchmark problems. Olusegun O. Faniran (10) explored concept of optimal planning of construction projects and developed relationship between planning input and the probabilities of achieving poor performance and good performance by modeling using logistic, linear, and curvilinear regression analyses. T. Horenburg (11) used computerized project management specifically Multi-Agent Negotiation technique to allocate resources to construction schedule and compared obtained results with Monte-Carlo-Simulations integrated in the same system and found that the results were reliable.

The conclusion from the above literature survey is that project scheduling problems of small sizes can be solved by the traditional optimization techniques. Whereas the number of projects and size of the project in terms of number of activities increase, the problem becomes more complex. Even more, the complexity increases when variety of resources is considered. In that scenario, it is not feasible to develop the project schedules by using the traditional optimization techniques.

III. METHODOLOGY

To meet a scheduled deadline or to minimize delay of any project manager will have to provide some extra resources in terms of funding or deliverables or manpower. This research will concentrate on providing a predefined extra funding to overcome the problem of delay in schedule. Provided extra funding will be utilized in crashing the critical activities which will ultimately result in reduction of total project duration. For better understanding details of completed construction site are consider. The steps listed below are followed in order to reduce its total duration.

A. Collection of Activity Data of any Construction Work

Table 1 shows various activities of any construction site.

ID	NAME	DURATION (Days)	COST (Rs.)	CRITICAL
BA000	Start office building addition project	0	0	No
BA400	Design Building Addition	23	2,24,498	No
BA501	Review And Approve Designs	9	73,206	No
BA640	Site Preparetion	18	1,25,914	No
BA680	Form/Pour Concrete Footings	10	4.37.609	No
BA681	Concrete Foundation Walls	10	3,07,465	No
BA690	Form and Pour Slab	5	1,92,776	No
BA710	Erect Structure Frame	20	2,76,556	Yes
BA712	Floor Decking	14	1,93,589	Yes
BA730	Concrete First Floor	15	3,13,566	Yes
BA735	Concrete Second Floor	15	3,13,566	Yes
BA860	Install Elevator Rails and Equipments	1	0	No
BA913	Install Elevator Cab and Finishes	2	0	No
BA411	Prepare and Solicit Bids for Heat Pump	3	15,617	No
BA413	Award Contract for Heat Pump	1	5,206	No
BA831	Set Heat Pump	5	0	No
BA871	Startup and Test HVAC	1	19,522	Yes
BA941	Test and Bala nce HVAC Equipment	1	19,522	Yes
BA850	Install Wiring and Cable	15	1,56,173	Yes
BA870	Connect Equipment	1	0	Yes
BA421	Prepare and Solicit Bids for Brick Exterior	3	15,617	No
BA423	Award Contract for Brick	1	5,206	No
BA600	Deliver Brick	1	0	No
BA750	Brick Exterior Walls	7	2,96,078	Yes
BA780	Insulation and Bui-up Roofing	10	97,608	Yes
BA790	Install Exterior Doors and Windows	2	0	No
BA890	Drywall in Offices	15	1,56,173	Yes
BA940	Touch-up and Clean-up	1	24,402	Yes
BA950	Finishes Complete	0	0	Yes
BA960	Punch List	2	48,804	Yes
BA901	Install Lighting Fixtures	3	0	No
BA912	Instal Plumbing Fixtures	2	0	No
BA620	Fabricate and Deliver Flooring	58	5,15,370	No
BA910	Install Floor and Carpenting	5	35,790	Yes
BA900	Install Ceiing Grid	15	5,28,710	Yes
BA911	Finish Carpentry and Millwork	5	52,058	Yes
BA930	Paint Building Interior	15	0	No
	TOTAL	314	4450601	

Table 1: Activity Details of Construction Site

B. Filtering Critical Activities and Calculating its per day cost

Table 2 shows Critical Activities and its Per Day Cost. Here to calculate per day cost of any activity it has been assumed that work done per day is same throughout the activity period and then dividing the total cost of an activity to number of days of that activity.

ID	NAME	PER DAY COST (Rs.)	DURATION (Days)	CRITICAL
BA710	Erect Structure Frame	13828	20	Yes
BA712	Floor Decking	13828	14	Yes
BA730	Concrete First Floor	20904	15	Yes
BA735	Concrete Second Floor	20904	15	Yes
BA871	Startup and Test HVAC	19552	1	Yes
BA941	Test and Balance HVAC Equipment	19552	1	Yes
BA850	Install Wiring and Cable	10411	15	Yes
BA870	Connect Equipment	0	1	Yes
BA750	Brick Exterior Walls	42296	7	Yes
BA780	Insulation and Bui-up Roofing	9760	10	Yes
BA890	Drywall in Offices	10411	15	Yes
BA940	Touch-up and Clean-up	24402	1	Yes
BA950	Finishes Complete	0	0	Yes
BA960	Punch List	24402	2	Yes
BA910	Install Floor and Carpenting	7158	5	Yes
BA900	Install Ceiing Grid	35247	15	Yes
BA911	Finish Carpentry and Millwork	10411	5	Yes
	TOTAL =	283010	142	

Table 2: Per Day Cost Of Critical Activities

C. Assuming amount of crashing of each activity and calculating cost of crashing of each activity and total cost of crashing.

Table 3 shows expected amount of crashing and maximum amount of crashing of each activity. To calculate cost of crashing of each activity multiply per day cost with number of days of crash.

ID	NAME	PER DAY COST (Rs.)	Maximum Crashing (Days)	Crash Cost (Rs.)
BA710	Erect Structure Frame	13828	3	55312
BA712	Floor Decking	13828	2	41484
BA730	Concrete First Floor	20904	2	62712
BA735	Concrete Second Floor	20904	2	62712
BA871	Startup and Test HVAC	19552	1	19552
BA941	Test and Balance HVAC Equipment	19552	1	19552
BA850	Install Wiring and Cable	10411	3	41644
BA870	Connect Equipment	0	0	0
BA750	Brick Exterior Walls	42296	2	84592
BA780	Insulation and Bui-up Roofing	9760	3	39040
BA890	Drywall in Offices	10411	2	52055
BA940	Touch-up and Clean-up	24402	1	24402
BA950	Finishes Complete	0	0	0
BA960	Punch List	24402	1	24402
BA910	Install Floor and Carpenting	7158	2	14316
BA900	Install Ceiing Grid	35247	3	140988
BA911	Finish Carpentry and Millwork	10411	2	31233
	TOTAL =	283010		689594

Table 3: Expected Crashing Cost of Activities

IV. RESULT

Now to get optimized crashing value of activities input this data to Excel Add-In called Solver**.** Solver runs on the parameters of linear programming and gives output in terms of optimized value with satisfying all the constrained conditions.

For the above mentioned project total duration of project is 314day. To reduce it by 25 days with maximum expense of Rs.500000 and simultaneously crashing of each activity should not exceed its maximum value.

Now for better understanding we put screen image of excel spread sheet and solver pop-up box and output given by solver. Refer Table 4, Figure 1, Table 5.

Activity Name	Original Duration	Crash Amount	Max. Crash	Cost Per Day
Erect Structural Frame	20	5	3	13827.8
Floor Decking	14	7	2	13827.78571
Concrete First Floor	15	6	2	20904.4
Concrete Second Floor	15	7	2	20904.4
Structure Complete	0	4	0	0
Rough In Complete	0	4	0	0
Startup and Test HVAC	1	0	1	19522
Test and Balance HVAC Equipment	1	3	1	19522
Install Wiring and Cable	15	6	3	10411.53333

Connect Equipment	1	5	0	0
Building Enclosed	0	0	0	0
Brick Exterior Walls	7	2	2	42296.85714
Insulation and Built-up Roofing	10	4	3	9760.8
Drywall in Offices	15	3	2	10411.53333
Touch-up and Clean-up	1	4	1	24402
Finishes Complete	0	6	0	0
Punch List	2	0	1	24402
Building Addition Complete	0	6	0	0
Install Floor and Carpeting	5	1	2	7158
Install Ceiling Grid	15	8	3	35247.33333
Finish Carpentry and Millwork	5	5	2	10411.6
TOTAL	142	86	30	283010.0429
CRASHING COST	1152400.081			
CRASH DURATION	56			

Table 4: Input Data For Solver

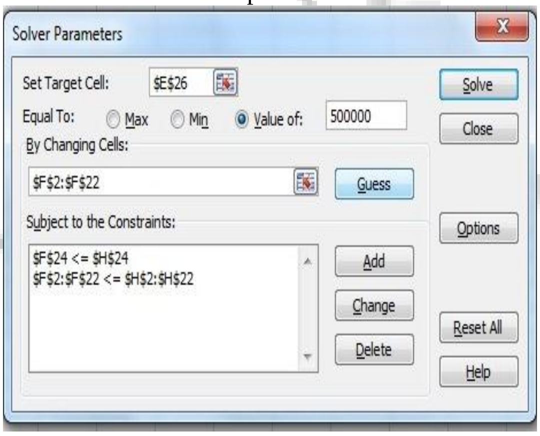

Fig. 1: Input Parameters for Solver

Activity Name	Original Duration	Crash Amount	Max. Crash	Cost Per Day
Erect Structural Frame	20	3	3	13827.8
Floor Decking	14	2	2	13827.78571
Concrete First Floor	15	2	2	20904.4
Concrete Second Floor	15	2	2	20904.4
Structure Complete	0	0	0	0
Rough In Complete	0	0	0	0
Startup and Test HVAC	1	1	1	19522
Test and Balance HVAC Equipment	1	1	1	19522
Install Wiring and Cable	15	3	3	10411.53333

Connect Equipment	1	0	0	0
Building Enclosed	0	0	0	0
Brick Exterior Walls	7	2	2	42296.85714
Insulation and Built-up Roofing	10	0	3	9760.8
Drywall in Offices	15	1.632988508	2	10411.53333
Touch-up and Clean-up	1	1	1	24402
Finishes Complete	0	0	0	0
Punch List	2	1	1	24402
Building Addition Complete	0	0	0	0
Install Floor and Carpeting	5	0	2	7158
Install Ceiling Grid	15	3	3	35247.33333
Finish Carpentry and Millwork	5	2	2	10411.6
TOTAL	142	24.63298851	30	283010.0429
CRASHING COST=	500000			
CRASH DURATION=	117.3670115			

Table 5: Output From Solver

V. CONCLUSION

In this study an attempt was made to optimize the schedule performance of the project by crashing the critical activities optimally. The model presented here works on parameters of Linear Programming and tries to give optimal solution by testing iteration cycle up to 100 times. The results given by model were compared with original crashing data of construction site and model shows superiority.

In actual project environment if a project is delayed then managers would have to pay a huge amount of money as a penalty or they may loose their security deposits in some cases. So to achieve deadline with minimum cost proposed model is useful to managers. For future work one can implant this model in multi-project environment or to get optimal output of any work this model can be used

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