COST OPTIMIZATION OF PROJECT BY CRASHING PROJECT SCHEDULE USING LINEAR PROGRAMMING

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Contents

Abstract

NB: This paper extended the work of (C. L. Karmaker* , P. Halder,2017).

In today's competitive surroundings finishing a project among time and budget, is extremely difficult task for the project managers. value and time alongside quality of the project play important role in construction project's decision. For surprising reasons, a project would possibly run behind the schedule that decision upon a project manager to blinking one or additional of the project's activities by hiring additional resources. On the choice of expediting the project, a linear programming math model was developed to attenuate the value of the project related to the expedition of activities. This aim of this study is to develop a model that finds a correct trade-off between time and price to expedite the execution process

1- Introduction

Project management is that the discipline of designing, organizing, securing, and managing resources to create the prospering completion of specific engineering project goals and objectives, many factors could cause delays equivalent to labor connected delay, political issues, contractor delay and a few unseen delays that contribute to extend the uncertainty. Critical path technique (CPM) is employed for correct project planning and programming of enormous projects. It objective is to ascertain a possible and fascinating relationship between the time and price of the project by reducing the target time and taking into consideration the value of expediting. per Pour et al. [1], time-cost trade Problem (TCTP) is taken into account together of the important selections in project accomplishment. the most objective of the time-cost trade-off problem (TCTP) is to minimize the initial project period obtained from the critical path analysis with the minimum direct and indirect price of the project. analysis on the TCTP was first conducted by Kelly in 1961. many researchers united that from 1961 the research principally targeted on the settled cases (Mobinia et al., 2011; Phillips and Dessouky, 1977;

Weglarz et al., 2011). The aim of this study is to develop a hybrid a model for distinguishing the optimum total price related to project duration. The time prices relation is then analyzed by multivariate analysis to get the target function. A Linear programming method model are going to be developed and solved using LINDO & MATLAB software.

2-Literature Review

2.1- General Linear programming model for CPM

The linear programming solution will indicate the earliest time of every node in thenetwork and the project duration

$$\min Z = X_n$$

subject to

$X_j - X_i \geq t_{ij}$ for all activities i , j

$X_i , X_j \geq 0$

Where

X_i = earliest event time of node *i*.

X_j = earliest event time of node *j*.

t_{ij} = time of activity *i -> j*.

n = number of the last node in the network.

2.2- Linear Programming model for crashing

The objective function is to reduce the project period at the minimum doable crash value. The objective function coefficients are the activity cost slope, the variable x_{ij} indicate the quantity of each activity will be reduced

$$\min Z = \sum_i \sum_j CS_{ij}.X_{ij}$$

Subject to

$X_{ij} \leq r_{ij}$

$Y_i + t_{ij} - X_{ij} \geq Y_j$

$Y_n \leq T$

$Y_i , Y_j , X_{ij} \geq 0$

Where

Y_i = earliest start event time of node i.

Y_j = earliest finish event time of node j.

n = number of the last node in the network.

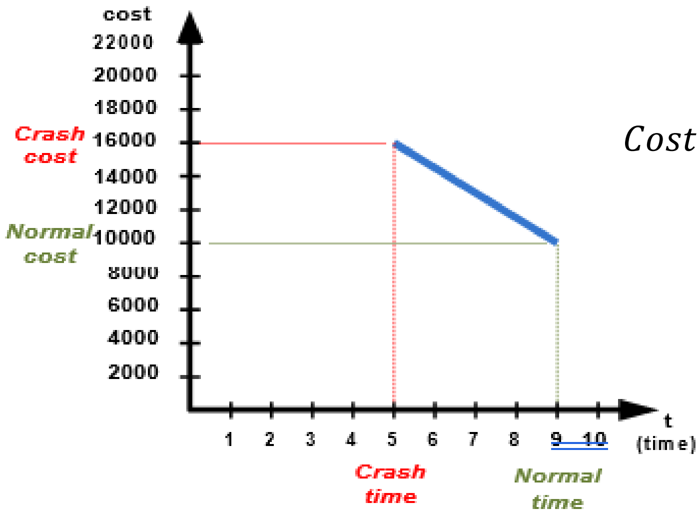
X_{ij} = amount activity i à j can be crashed.

r_{ij} = number of the range amount activity i à j can be crashed.

T = Targeted project completion time.

CS_{ij} = Cost Slope of activity i à j.

If we suppose that the relationship between crash cost and crash time is linear, then an activity can be crash by $ cost slope per time.



$$Cost\ Slope = \frac{Crash\ cost - Normal\ cost}{Normal\ time - Crash\ time}$$

3-<u>Methodology</u>

The overall procedure for scheduling project crashing time with the minimum total cost can be summarized as follows:

I. Draw the project network.

II. Perform CPM calculations and identify the critical path, using normal duration and costs for all activities.

III. Compute the cost slope for each activity.

IV. Formulate project time-cost crash problem as a linear programming (LP) model.

V. Optimize the objective function.

Case Study

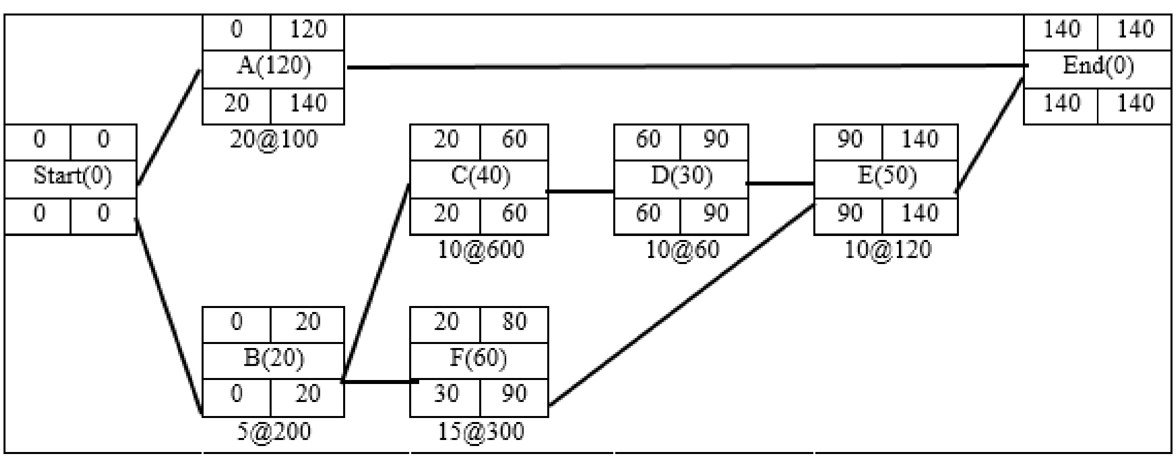
Our case study is about a project manager who wishes to complete a construction operation within 120 days, while the normal duration is 140, this means that he needs to crash project by 20 days. The project data of a construction problem provided by the project manager is shown in Table 1.

Table1

Activity code	Immediate predecessors	Normal cost ($)	Normal duration (Days)
A	-	12000	140
B	-	1800	20
C	B	16000	40
D	C	1400	30
E	D, F	3600	50
F	B	13500	60

Table 1 presents the details description of all activities required for the completion of the construction project. Here, there are five activities and construction process start with activity A and ends with activity F.

I- Network Project



II- Critical Path

To determine the critical path consisting of activities with zero slack, completely different variables equivalent to Earliest begin (ES), Earliest end (EF), Latest begin (LS), Latest end (LF) and Slack are computed. Table 3 shows the computation of the critical path of the project. Table 2 shows that the entire period for the completion of the project is a 140, the critical path is B-C-D-E.

Table 2

Activity code	Earliest Start (ES)	Earliest Finish (EF)	Latest Start (LS)	Latest Finish (LF)	Slack (LS-ES)	Critical
A	0	120	20	140	20	No
B	0	20	0	20	0	Yes
C	20	60	20	60	0	Yes
D	60	90	60	90	0	Yes
E	90	140	90	140	0	Yes
F	20	80	30	90	10	No

III- Determination of cost-slope of each activity

Project durations are often reduced by taking many measures equivalent to overtime, hiring additional workers, exploitation special time-saving materials, and special equipment. Table four shows the calculation of the cost-time slopes of the activities by a heuristic methodology named the cost-lope method. Table 3 depicts a project with hypothetical normal time- cost data and crash time–cost data of necessary activities. Activity C requires highest amount of cost whereas highest normal time duration in days is 120 for activity A.

Table 3

Activity code	Immediate predecessors	Normal cost ($)	Normal duration (days)	Crash cost ($)	Crash duration (days)
A	-	12000	120	14000	100
B	-	1800	20	2800	15
C	B	16000	40	22000	30
D	C	1400	30	2000	20
E	D,F	3600	50	4800	40
F	B	13500	60	18000	45

To expedite the project by reducing the expected project duration more down from 140 days, a method of unmitigated the period of activities has been anticipated. Reduction of project duration incurs the additional cost. Table 4 shows the calculation of the cost-time slopes of the activities by a heuristic method namedthe cost-lope method

Table 4

	Normal		Crash				
Activity Code	Duration (days)	Costs ($)	Duration (days)	Costs ($)	Crash cost-Normal cost (ΔC)	Normal time-Crash time (Δt)	Cost slope ($\Delta C/\Delta t$)
A	120	12000	100	14000	2000	20	100
B	20	1800	15	2800	1000	5	200
C	40	16000	30	22000	6000	10	600
D	30	1400	20	2000	600	10	60
E	50	3600	40	4800	1200	10	120
F	60	13500	45	18000	4500	15	300

5- Model Implementation

The start time of each activity depends on the start time and duration of each ofits predecessors.
The immediate predecessor of activity C is B, then start time of activity C is as follows:

Thus, activity C cannot start until activity B starts and then completes its duration of 20 − X_B.

Including all these relationships the objective function of the proposed model can be formulated as (Min total cost):

$$Z = 100X_A + 200X_B + 600X_C + 60X_D + 120X_E + 300X_F$$

Constraints (Maximum reduction constraints):

$X_A \leq 20$

$X_B \leq 5$

$X_C \leq 10$

$X_D \leq 10$

$X_E \leq 10$

$X_F \leq 15$

Start times constraints

$Y_c - Y_B + X_B \geq 20$

$Y_D - Y_C + X_C \geq 40$

$Y_E - Y_D + X_D \geq 30$

$Y_E - Y_F + X_F \geq 60$

$Y_F - Y_B + X_B \geq 20$

$Y_{Finish} - Y_B + X_A \geq 120$

$Y_{Finish} - Y_E + X_E \geq 50$

Project duration constraint:

$Y_{Finish} \leq 120$

Non-negativity constraints:

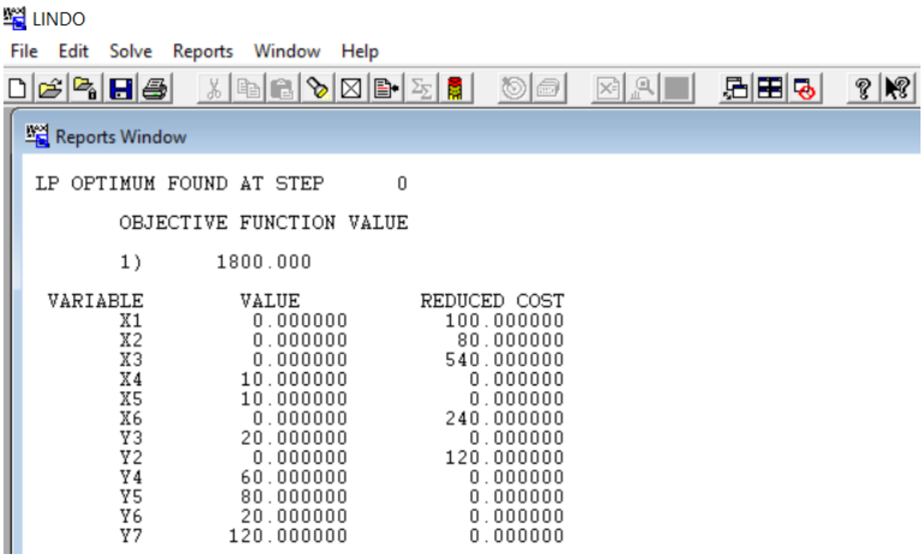
$X_i \geq 0$; $i = A, B \ldots \ldots, F$

$Y_i \geq 0$; $i = C, D \ldots \ldots, F$

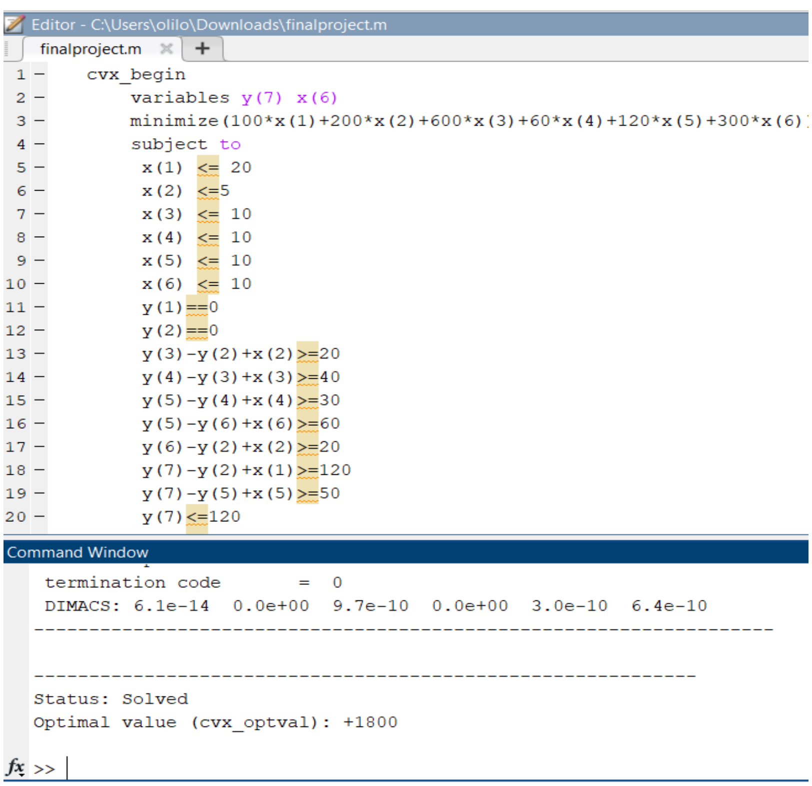
$Y_{Finish} \geq 0$

6-Results

In this study, LINDO & MATLAB software are used to optimize the proposed model and the solution of the model is presented in Table 5. Previously, the total duration and expected total cost for the completion of the project were 140 days and $48300



However, MATLAB & LINDO shows that additional cost for crashing activities and to complete the projectby 120 days is $1800. To meet the 120 days durations, we must reduce activity D and E by 10 days with an additional cost of $1800.So, through proper scheduling, the activities project completion time is reduced by 20 days which increases the initial expected cost from $48300 to $ 50100.



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