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COST OPTIMIZATION OF PROJECT BY LINEAR PROGRAMMING,

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Abstract: Project scheduling is very essential part of the project planning phase. Cost optimization of project can be achieved by completing the project before the completion time of the project, which saves additional overhead cost of the construction project. To complete the project work before the scheduled time activity crashing is the best solution to that. Project having more activities can be difficult and so linear programming technique can be applied to the project crashing work and the optimum value to crash the project duration for the desired time can be calculated using LINDO (linear programming software). Three different options are selected having different construction materials for a defined size of floor work. Crashing of project is carried out for a commercial building 4192 sq ft super built up area.

Key Words: planning, scheduling, , crashing, linear programming

1.Introduction

Project scheduling is very essential part of the project planning phase. Cost optimization of project can be achieved by completing the project before the completion time of the project, which saves additional overhead cost of the construction project. To complete the project work before the scheduled time activity crashing is the best solution to that. Project having more activities can be difficult and so linear programming technique can be applied to the project crashing work and the optimum value to crash the project duration for the desired time can be calculated using LINDO (linear programming software). Three different options are selected having different construction materials for a defined size of floor work. Crashing of project is carried out for the one floor of the apartment of MIG housing scheme having 4192 sq ft super built up area.

Critical path method(CPM) and Project evaluation and review techniques(PERT) are both the very basic concept of the project planning. Project scheduling is also very essential part of the project planning stage. Project scheduling can be carried out using MSP (Microsoft project) software. Sometimes project is not running according to the scheduled time of the project. Sometimes delays in project can be occurred due to various reasons like site accidents, weather effect, natural calamities, financial crises, etc. In that cases project have to take back on the scheduled time and for that crashing of project activities is a best solution. With bigger project work more activates are there to crash which can be very complex to solve manually. in that case linear programming techniques are applied to the crashing problem of the project work. Linear programming is nothing but the mathematical formulation of the crashing project and solution of the problem is carried out in LINDO software.

LINDO is linear programming software to solve the very complex formulas easily. In linear programming Main formula of optimization is formulated and the different constraints on which that main formula depends are formulated. Crashing of activities can reduced the construction time but for crashing the activities some cost is needed which is the cost of the resources needed to complete the activity before the given completion time of the project. Thus crashing of activities adds additional cost to the total project cost. But reduction in the total completion time of the project can reduce the overhead cost of the project which impact more than the additional crash cost of the activities.

2. Scheduling of construction project

Scheduling in construction projects is the process of listing of tasks, activities, milestones with a planned start and finish date. The importance of scheduling in construction projects cannot be neglected since it plays a crucial role in a project's success. Proper scheduling would ensure the completion of the project on time and within budget. Not only does it outline the pace of the work but also how the tasks are executed. Added to that, scheduling defines method and sequence in which materials are delivered. Finally, it permits adjustments to accommodate changes and unanticipated events.

Importance of Scheduling In Construction Projects are:

- It assign dates to the project activities
- Construction companies would be able to see whether the duration stipulated by the client is obtainable or not. In this case, penalizing due to late completion of project can be avoided.
- Based on construction project scheduling, the preliminary costs can be estimated.

- The schedule is useful for formulating tender or bid estimates.
- Project scheduling is intended to match the resources of equipment, materials and labor with project work-tasks over time.
- It provides a sequence of tasks. So, the project manager knows what activities they need to be working on, and what are the next activities they need to be prepared for.
- Improving safety performance by sequencing the activities to ensure maximum protection for workers.
- It enables construction team to see their goals and when they need to be achieved.
- It is possible to change the sequencing of activities and extend or shorten the durations in such a manner that the use of resources is smoothed and optimized.
- It eliminates problems due to production bottlenecks.
- It ensures the completion of a project as soon as possible.
- It helps avoid delays in the completion of an entire project, hence avoid creation of havoc for owners who are eager to start using the constructed facilities.
- Detailed construction schedules can be used by the owner as a means of monitoring the work progress.
- It can help compare actual work performed with the schedule to determine if construction is proceeding satisfactorily.
- Planned schedule and the actual accomplishments can be compared to allocate the liability for project delays due to changes requested by the owner, worker strikes or other unforeseen circumstances.

Construction Scheduling Techniques:

➢ Using Bar Charts

Bar Charts are the most simple and easiest way to generate construction schedules. It is widely used due to its simplicity and multiple adaptations to numerous events. A bar chart is formed with a list of activities, specifying the start date, duration of the activity and completion date of each activity, and then plotted on a project timescale. The detailed level of the bar chart depends on your project complexity and the intended use of the schedule.

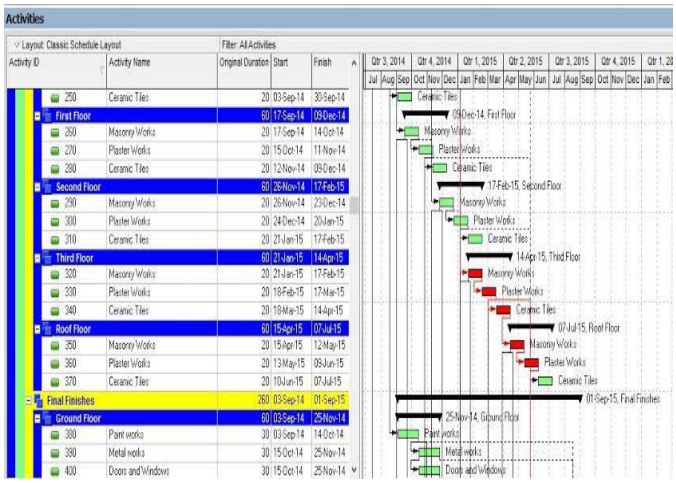

Fig-1: scheduling of project

➢ Critical Path Method

This process is more complex and detailed than the previous one. With a large list of activities, each activity is then linked to previous and subsequent activities, specifying that each activity has at least another one that must be completed prior to starting the preceding one. The Critical Path Method establishes and assigns start and end dates based on certain logic like FS, FF, SS, SF that are key indicators of how activities must be sequenced.

➢ Line of balance scheduling

This construction scheduling process is a planning technique for repetitive work. The essential procedure for this scheduling technique is to allocate the resources needed for each step or operation, so the following activities are not delayed, and the result can be obtained.

➢ Q scheduling

Q Scheduling is quantitative scheduling, in the context that quantities to be executed at different locations of the construction project form the elements of the schedule. Also, Q Scheduling is Queue Scheduling in the context that trades pass through the different segments of the project in a queue sequence.

3. Network diagram of the project

A network diagram is a graphical representation of all the tasks, responsibilities and work-flow for a project. It often looks like a chart with a series of boxes and arrows. It is used to map out the schedule and work sequence for the project, as well as track its progress through each stage, up to and including completion. Since it encompasses every single action and outcome

associated with the project, a network diagram also illustrates the scope of the project. A network diagram not only allows a project manager to track each element of a project and quickly share its status with others.

Basic definitions in network diagram

- Predecessor Activity/Milestone – It is simply called as a Predecessor. A Predecessor logically comes before the dependent activity/milestone in a Project Network Diagram.
- Successor Activity/Milestone – It is simply called as a Successor. A Successor is the dependent activity/milestone. It logically comes after Predecessor(s) in a Project Network Diagram.
- Node – All the activities/milestones (and Successors) in a Project Network Diagram are represented on a Node.
- Activity – Usually an activity is drawn as a rectangle.
- Milestone – Usually a milestone is drawn as a small circle. A project can have start and finish milestones as well as intermediate milestones.
- Arrow – Dependencies between activities/milestones are represented as arrows. Two related nodes are separated by a unidirectional arrow.

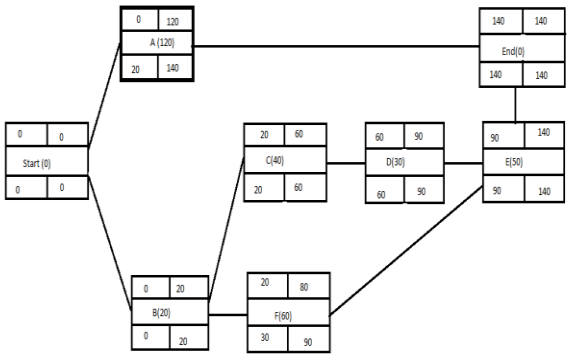

Fig-2: Network diagram of a project

4. Critical path analysis

The critical path is the longest sequence of activities in a project plan which must be completed on time for the project to complete on due date. An activity on the critical path cannot be started until its predecessor activity is complete; if it is delayed for a day, the entire project will be delayed for a day unless the activity following the delayed activity is completed a day earlier**.** When the critical path has been identified, it can clearly be seen where effort cannot be compromised. If any of the activities on the critical path change, the end date of the project will be affected. The work needed to complete the project needs to be broken down and all activities need to be defined.

Early Start	Duration	Early Finish
Activity		
Late Start	Float	Late Finish

Fig-3: Activity representation

Early Start – The earliest time that an activity can start according to the logical constraints.
Duration – The estimated time to undertake the activity.
Early Finish – The earliest time that an activity can finish according to logical constraints.
Late Start – The latest time that an activity can start according to logical constraints and without affecting the overall project duration.
Float – The time by which an activity may be delayed without affecting the overall project duration.
Late Finish – The latest time that an activity can finish according to logical constraints and without affecting the overall project duration.
Early Start + Duration = Early Finish

Critical path diagram is a live art effect. Therefore, this diagram should be updated with actual values once the task is completed. This gives more realistic figure for the deadline and the project management can know whether they are on track regarding the deliverables. Critical path identification is required for any project-planning phase. This gives the project management the correct completion date of the overall project and the flexibility to float activities. A critical path diagram should be constantly updated with actual information when the project progresses in order to refine the activity length/project duration predictions.

5. Analysis by linear programming project soft wear

Linear programming is nothing but the mathematical formulation of the crashing project and solution of the problem is carried out in LINDO software. LINDO is linear programming software to solve the very complex formulas easily. In linear programming Main formula of optimization is formulated and the different constraints on which that main formula depends are formulated. Crashing of activities can reduced the construction time but for crashing the activities some cost is needed which is the cost of the resources needed to complete the activity before the given completion time of the project. Thus crashing of activities adds additional cost to the

total project cost. But reduction in the total completion time of the project can reduce the overhead cost of the project which impact more than the additional crash cost of the activities.

Variables of the problem

Let Z be the total cost of crashing activities. The problem then is to minimize Z, subject to the constraint that project duration must be less than or equal to the time desired by the project manager. The natural decision variables are :

Xj = reduction in the duration of activity j due to crashing this activity, for j = 1,2,3…7.

YFINISH = project duration.

Yj = start time of activity j (j = 1,2,3….7).

Here (Yj) = (start time + normal duration - crash duration) for this immediate predecessor.

Thus Problem statement will be,

Minimize Z =∑ .

Subject to,

a) Non negativity constraint, Xj>=0 (j = 1,2,3…7), Y1 = 0, Yj>=0(j = 2,3,4…7)

b) Maximum reduction constraints, Xj <= crash duration (j = 1,2,3…..7)

c) Start time constraint , Yj = Duration of (j-1) activity - X(j-1)

d) Project duration constraint, Yfinish <= Total Crash Duration.

Solution of the formula is generated using LINDO software (linear programming software).

5. Result And Discussion

Table 1. Construction project data.

Activity code	Immediate predecessors	Normal cost	duration (Days)
A	-	12000	120
B	-	1800	20
C	B	16000	40
D	C	1400	30
E	D,F	3600	50
F	B	13500	60

Table 2. List of normal and crash cost-time data.

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	20
D	C	1400	30	2000	20
E	D,F	3600	50	4800	40
F	B	13500	60	18000	45

Table 3. Cost-time slope of the activities.

Activity Code	Normal Duration (days)	Normal Costs	Crash Duration (days)	Crash Costs	Crash cost-Normal cost (ΔC)	Normal time - Crash time (Δt)	Cost slope (ΔC/Δt)
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

Figure 1. Precedence diagram of all activities.

In this study, LINDO software is used to optimize the proposed model and the solution of the model is presented in Table 4. Previously, the total duration and expected total cost for the completion of the project were 140 days and 48300 rupees..

Table 4. Solution of the model.

Objective value	Final value	Reduced value
Z1	1800	0
XA	0	100
XB	0	80
XC	0	540
XD	10	0
XE	10	0
XF	0	240
YA	0	0
YB	0	120
YC	20	0
YD	60	0
YE	80	0
YF	20	0

Y_{finish}	120	0

However, Table 4 shows that additional cost for crashing activities and to complete the project by 120 days is 1800 rupees. So, through proper scheduling, the activities project completion time is reduced by 20 days which increases the initial expected cost from 48300 to 50100 rupees.

6. Conclusions

The main goal of this study is to schedule the jobs/activities of a construction project in such a way that expedites the execution of the project. CPM method is used to identify the critical path and estimate the project completion time. Linear programming (LP) approach is suggested to crash the activities of the project. Reduction of 20 days from 140 days estimated by CPM increases the total cost by 1800. The model indicates that about 17% decrease of time can be achieved by increasing cost by 3.73%, which is satisfactory. The contribution of the model is its simplicity of use and project manager can schedule all activities effectively. Different optimization tools like particle swarm optimization (PSO), mixed integer linear programming (MILP) and, fuzzy multi-objective linear programming (FMOLP) etc. can be used to obtain the solution.

References

[1] Abdelhak Challal, Mohamed Tkiouat, Mohammed V . *The Design of Cost Estimating Model of Construction Project: Application and Simulation*, University Agdal-Mohammadia School of Engineering, Rabat, Agdal Maroc.

[2] Agarwal, A., Colak, S., & Erenguc, S.. *A neurogenetic approach for the resourceconstrained project scheduling problem*. Computers & operations research, 38(1), 44-50, (2017)

[3] Grit Ngowtanasuwan, Mahasarakham. *Mathematical Model for Optimization of Construction Contracting in Housing Development Project*, University, Mahasarakham 44150, Thailand

[4] J. Farkas and K Jarmai, *optimum design of steel structures,* Springer, p.265, 2013

[5] J. Smith , J. Hodgins, A. Witkin, *creating models of truss structures with optimization, ACM Transaction on Graphics*.(TOG), VOL.21, NO.3, PP. 295-301,2012.

[6] M. Asadujjamanand M. Babul Hasan, *A proposed technique for solving quasi-concave quadratic programmingproblems with bounded variables*, Dhaka university journal of science , vol.63, no.2, pp. 111-117,2015

[7] Omar M. Elmabrouk and Fardous Aljiebali. *Crashing Project Activities Using Linear Programming Technique*, Benghazi University, Libya.

[8] Pour, N. S., Modarres, M., & Moghadam, R. T. (2018). *Time-cost-quality trade-off in project scheduling with linguistic variables. World applied sciences* journal, 18(3), 404-413.

[9] Rama.S,Srividya S, Deepa, *A Linear Programming Approach For Optimal Scheduling Of Workers In A Transport Coorperation*, v 45(10), pp. 482-487,2017

[10] S. Kravanja and T. Zula, *cost optimization of industrial building structures, advances in engineering softwear,* vol. 41, pp. 442-450,2014

[11] T. Balogh and L. G. Vigh,cost optimization of steel building structures, *World Academy Of Scienece ,Enginnering And Technology*, Vol. 7, pp. 1016-1025.,2013.