

Implementation of Line of Balance Method for Scheduling High-rise Building

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ABSTRACT

In linear construction projects like high rise buildings, roadways, pipelines where activities are repeated after a specific interval, it is very much important for project manager to monitor the project at each stage. Line of Balance method is therefore useful for the project like high rise building to monitor the progress of the work. This method is useful for calculating the total duration of the project, crew synchronization and also shows the process, status, timing and phasing of the project activities. The overall objective of this study is to identify the total duration required by the project for its completion and its comparison with the actual plan by using Line of Balance method, to crash some of the activities and find out the total duration of crashed activities and to calculate labours required for the crashed activities by drawing the graph of Histogram. **Keywords-** crashing, crew synchronization, buffer, Histogram, Rate of Production

I. INTRODUCTION

A. BACKGROUND

The Line of Balance Scheduling Technique was originated by the Goodyear Company in the early 1940's and was developed by the U. S. Navy in the early 1950's for the programming and control of both repetitive and non-repetitive projects. The construction of projects of repetitive units can be considered as the continuous manufacturing of many units requiring a certain period of time for each unit to be completed. It can be used in projects involving activities of repetitive nature such as housing projects, high rise buildings, long bridges, highway construction, and pipelines (Lumsden, 1968). The LOB was first applied to industrial manufacturing and production control, where the objective was to evaluate a production line flow rate of finished products. The line of balance method is based on underlying assumption that the rate of production for an activity is uniform. The basic concepts of LOB have been applied in the construction industry as a planning and scheduling method in Finland in the 1980s (Harris and McCaffer, 1989).

The LOB chart provides an overview of the project's overall status by quantitatively representing the cumulative completion of activities at a given point of time. It graphically reveals any imbalance that suggests a deviation in the progress of activities which enables the management to focus on assessing the deviation quantitatively (Khisty 1970).

B. AIMS AND OBJECTIVES OF STUDY

The main purpose of applying Line of Balance method to high rise building is to:

- Draw the graph of repetitive activities, as applying LOB facilitates the continuous monitoring of the project, at each stage.
- Calculate rate of production of work.
- Compare the cost of actual and delay project.
- Draw the graph of activities after crashing, and to know the rate of flow of the activities.
- Evaluate size of crew required for the crashed activities.

C. LIMITATIONS

The study is limited to the following respects

- Inability to generate a clear critical path of the project schedule, relative to the one provided by CPM schedules.
- In CPM scheduling the user could divide project by location and other systems like trades, in LOB only location.
- Productivity rates in LOB schedule do not include the effect of crews "learning curve, or if the individuals working in the crews changed".

II. LITERATURE REVIEW

i. PRACTICAL LIMITATIONS OF LINE OF BALANCE IN SCHEDULING REPETITIVE CONSTRUCTION UNITS

In this paper the author has explained, about practical limitations, and constraints while using Line of Balance method and also have studied different factors to be considered while drawing as well as using LOB.

Logical sequence: Scheduling construction projects with repeating activities are performed based on a combination of network technology and the basic concept of LOB. The precedence relationships

define the logical sequence between successive construction activities. All types of logical precedence relationships between succeeding activities (start-to-start; start-to-finish; finish-to-finish and finish-to-start) can be represented in the unit network.

Crew work continuity: The application of such work continuity during scheduling of repetitive construction leads to the following managerial function: (i) maximize the benefits from the learning curve effect for each crew. These results have considerable savings in time and cost. (ii) Minimize the idle waiting intervals of equipment and labour. (iii) Minimize extra effort associated with work interruptions such as- setup time, temporary storage of tools and materials.(iv) Minimise the off-on movement of crews on a project once work has begun.

Number of employed crews: The crew availability constraint depends on the available number of crews that can be assigned to activity in all repetitive units of the construction project. Making the schedule resource oriented, maximum efficiency can be adopted.

Work crew size: A crew of optimum size is defined as a combination of trade workers, materials, and equipment that usually guarantees maximum productivity in an activity. This crew is expected to carry out the related activity in the most cost efficient way.

Project resources: The distribution of resources during the project process is one of particular importance for construction managers. Not only do managers have to make sure that the resources they allocate to the activities do not exceed availabilities. They would also want to see as smooth a distribution as possible to avoid the disruption of hiring and firing crews during the project progress.

Workflow direction: Upward direction: Most work is scheduled in upward direction to follow the construction of skeleton.

Downward direction: Some other construction activities, how-ever, are scheduled in a downward direction for reasons (i.e., safety or to prevent damage of the installed work). The final finishing of external cladding, clearing, and cleaning could be the typical examples of such activities.

Author concluded that several issues associated with LOB application have been identifies in this research. The research determines the practical limitations of LOB in scheduling repetitive construction units.

ii. LOB AND CPM INTEGRATED METHOD FOR SCHEDULING REPETITIVE PROJECTS

It is said that repetitive projects require schedules that ensure the uninterrupted usage of resources from a unit to similar units in a repetitive activity while

maintaining logical dependency constraints and the critical path method(CPM) is the most widely used and accepted planning and scheduling method for non-repetitive projects, but does not suit the planning and scheduling method for repetitive projects. On the other hand, Line of Balance(LOB) has been used in scheduling repetitive activities, which is a resource driven technique.

Author made few attempts to combine the benefits of CPM and LOB technique in planning and scheduling of repetitive projects. He developed an integrated CPM and LOB model to schedule repetitive projects in an easy non-graphical manner, considering both resource continuity constraints and logic dependencies. The activities which overlaps of a single typical unit are used to model duration and logical relationships of repetitive activities.

He proposed a model which consists of four steps:

- (i) LOB calculations: The objective of LOB formulation is to achieve a resource- balanced schedule by determining the number of crews to be employed in each repetitive activity. This is conducted such that the units are delivered with a rate that meets a pre-specified project deadline and crew's work continuity is maintained.
- (ii) Calculating activity duration: Overlapping activities are generalized to represent repetitive activities. For this, the duration is assumed constant in all units of a repetitive activity.
- (iii) Specifying logical relationships using Overlapping activities: The logical dependency relationship among different activities can be specified according to the selected rate of progress of each activity. It significantly maintains the work continuity.
- (iv) Time scheduling: After LOB calculations and the relationship type among the consecutive activities specified with their associated lags, time analysis similar to that of CPM can be performed.

The Author further concluded that scheduling of repetitive projects represents a challenge for construction planners and managers. Classical CPM analysis does not suit characteristics of repetitive projects, whereas LOB lacks the analytical qualities of CPM scheduling.

iii. SCHEDULING PROJECT WITH REPETITIVE ACTIVITIES

Authors have explained the repetitive scheduling method(RSM), which recognizes the technical constraints of CPM and they also includes an additional resource continuity constraints to ensure continuous resource usage. They also said that construction contractors are often faced with projects containing multiple units wherein activities repeat from unit to unit. Therefore these projects require

schedules that ensure the uninterrupted usage of resources from an activity in one unit to a similar activity in the next unit.

RSM method can be applied to both horizontal and vertical projects containing either discrete or continuous activities. An RSM schedule can be presented graphically as an X-Y plot of a series of production lines, all of which represent a repetitive activity.

They have also explained about the controlling sequence of activities as a new concept for the determination of the project duration which is introduced by RSM. This sequence includes activities between control points on successive unit production lines and extends from project start to project finish.

Lastly they concluded that the use of typical CPM scheduling techniques cannot ensure this continuity in resource utilization because only technical precedence and resource availability constraints are shown in CPM networks. The RSM finds the additional resource continuity constraint that cannot be shown in a network, and thus provides for continuous resource usage.

III. METHODOLOGY

It is difficult for the project manager to find which activity is going on particular floor when it comes to the construction project that is broken down into a large number of activities. Application of Line of Balance scheduling technique can be done to the project consisting of repetitive activities as it facilitates the continuous monitoring of the project, at each milestone.

The main objective of this study is to draw line of balance graph for repetitive activities and compare the actual and delay work at each stage of work and crash the activities which are critical and to draw the inferences.

- **Data Collection:** For drawing Line of Balance graph, repetitive activities and their duration should be known.
- **Bar chart:** The bar chart is pictorial representation in two dimensions of the project. The project is broken down into a number of independent manageable jobs or units known as activities for which suitable work duration is decided on the basis of available resources.

- **Drawing Line of Balance diagram:** In LOB, the time is plotted on X axis and the units or stages on Y axis. The production rate of an activity is the slope of the production line and is expressed in terms of units per time. The line of Balance technique assumes that the rate of production for an activity is uniform. In other words the rate of production is linear. The Line

of Balance technique uses man-hour estimate and optimum crew size.

The two oblique and parallel lines used in line of balance technique denote the start and finish times of each activity in all the units from first to last.

- **Plotting Histogram:** A histogram is a bar graph of raw data that creates a picture of the data distribution. In my case Histogram will show what is the maximum and minimum number of labours required for a given period. Also, it will be drawn for the crashed activities to find out number of labours required.
- **Calculation of Cost of the Project:** Crashing of activities will be done by reducing the duration of the activities and increasing the resources, therefore, it will effect on the total cost of the project. Hence calculation of the cost of the project will be done after crashing of activities.
- **Inferences:** From the Line of Balance graph of the actual activities and the crashed activities, inferences will be drawn whether this method is suitable for crashed activities or not and the crew size will be calculated from Histogram.

IV. FINDINGS FOR THE STUDY

For applying line of balance method to schedule high-rise building, the activities like brickwork, internal plaster, plumbing work, electrification work, tiling, door and window frames, painting etc. which are repeated from one floor to another and their durations are collected.

The activities are then arranged in successive manner and the graph of Line of Balance is drawn by giving buffers at the top or bottom of the activity in order to get the total duration of the project and to get crew work continuity and rate of production is calculated.

From graph it has seen that the duration of the project is more. In order to reduce the duration of the project, some activities which are critical and are taking longer duration have to crash.

The critical activity has crashed by reducing the duration and Line of Balance graph is drawn and from graph it has been seen that the total duration of the activity is reduced.

For getting the maximum and minimum number of labours required, a graph is plotted for the requirement of resources against the period of requirement which is known as Resource Usage Profile or in general language of statistics a Histogram.

The Histogram is drawn for the actual work to know the maximum and minimum number of labours required for the project for the given period.

Another graph of Histogram is drawn for the crashed work to evaluate the number of labours required for the crashed activity which is known as Representation of Resources.

From the second graph of Histogram, Rate of Production for the crashed activity is calculated by using formula;

$$R = \frac{C}{D}$$

Where,

R= Rate of Production

C= No. of crews/day

D= Duration(days)

Therefore, Rate of Production for the crashed activity has been increased.

V. CONCLUSION

In high rise buildings, same activities are repeated on each floor. In order to trace which activity is going on particular floor, Line of Balance method can be used. It is a graphical representation of repetitive activities where project manager can compare the planned and actual rate of production and if the project is lagging behind the planned schedule, the project manager can take suitable action.

LOB and CPM method can be integrate for scheduling repetitive activities, since to crash the activity, critical activity should be known therefore CPM can be used in Line of Balance method.

Since the activities are crashed to reduce the duration of the project, but the cost of the project will increase since the resources have to increase for the project to be completed in stipulated time. Therefore total cost of the project will increase by some amount.

The study is limited to the projects where activities are repeated in linear way or non-linear way.

REFERENCES

Journal Papers:

- [1] Sherif Mohamed Hafez,(2004), “ Practical limitations of line of balance in scheduling repetitive construction units”, *The Alexandria Engineering Journal*, Vol. 43, No. 5,pp (653-661).
- [2] Mohammad A. Ammar, “LOB and CPM Integrated Method for Scheduling Repetitive Projects”, *Journal of Construction Engineering and Management*, vol. 139, No.1, January 1, 2013.
- [3] David Arditi, M.ASCE¹;Onur B. Tokdemir²; and Kangsuk Suh³, “Challenges in Line-of-Balance Scheduling”, *Journal of Construction Engineering and Management*, vol. 128, No.6, December 1, 2002.

- [4] Robert B. Harris¹, Fellow, ASCE, and Photios G. Ioannou², Member, ASCE, “Scheduling Project with Repetitive Activities”, *Journal of Construction Engineering and Management*, vol. 124, No.4, July/August, 1998.
- [5] BY I-Tung Yang and Photios G. Ioannou, (2002), “Resource-Driven Scheduling For Repetitive Projects: A Pull- System Approach” thesis work, pp (1-14) Science Direct.
- [6] Gregory A. Duffy, Garold D. Oberlender; and David HyungSeokJeong, “ Linear Scheduling Model with Varying Production Rates”, (2011), “Journal of Construction Engineering and Management” , *The Journal of Construction and Management*, Vol.I, pp (254-266).
- [7] Magdalena Rogalska, Zdzislaw Hejducki,(2007), “ Time Buffers in Construction Process Scheduling”, *The Journal of Civil Engineering and Management*, Vol XIII, No 2, pp(143-148).
- [8] Recardo Mendes Jr. and Luis Fernando M. Heineck, (98),“Preplanning Method for Multi-Story Building Construction Using Line of Balance”, *Proceedings IGLC 98*.

Books:

- [1] K.K. Chitkara, *Construction Project Management*, pp (205-210).
- [2] K. Nagarajan, *Project Management*, pp(89-92).