

# A Case Study: Line of Balance (LOB) Method for High Rise Residential Project

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## ABSTRACT

*India is the second largest in construction industry. For growing need for shelter it is important that requirement of resources should be delivered on time. Linear scheduling methods is best suited to projects that display repetitive characters but their use in the construction industry is limited. Line of balance is linear scheduling method that also makes use of network technology. The Line of balance method is well suited to projects that are composed of activities of a linear and repetitive nature. Line of balance method of scheduling for project comprised of work of repetitive natures which involved in housing project, urban residential development, roads construction, high-rise construction buildings, pipelines, precast concrete production etc. To monitor the project LOB method become easier to visualize and operate using set of flow line graph where Gantt chart graph do not give much details. It is important for project manager to handle the project within specific set of limitation where resources are available and optimum use. The overall objective of this study is to identify the total duration required by project for its completion and comparison with actual plan by using line of balance method and find out the float the project and representing the project with the use of flow line chart for repetitive nature of activities.*

**Keyword:** - Line of balance (LOB), Repetitive nature, Scheduling, line chart, Gantt chart.etc.

## 1. INTRODUCTION

Line of balance (LOB) is a management control process used in construction where the project contains blocks of repetitive work activities, such as roads, pipelines, tunnels, railways and high-rise buildings, precast construction, row houses etc.. It is a control process for collecting facts relating to time, cost and schedule accomplishment, all the project related task is measured against specific plan. LOB shows the process, status of project, crew size continuity, and background of work, time and phase of project activities providing management with measuring tools. LOB assists project management by comparing a formal objective against actual progress, examining only the deviations from established plans, and gauging their degree of severity with respect to the remainder of the project, dealing with problem and trouble causing areas and problem solving within specific constrains.

1. Forecasting future performance.
2. A programmed rate of completed units is met.
3. A constant rate of repetitive work is maintained.
4. Labour and plant move through the project in continuous manner such that a balanced labour force is maintained and keep fully employed.
5. The cost benefits of repetitive working are achieved.

Line-of-balance (LOB) is a variation of linear scheduling methods that allows the balancing of operations such that each activity is continuously performed. The major benefit of the LOB methodology is that it provides production rate and duration information in the form of an easily interpreted graphics format. The LOB plot can show at a glance what is wrong with the progress of an activity, and can detect potential future bottlenecks. Obviously, LOB allows a better grasp of a project composed of repetitive activities than any other scheduling technique, because it allows the possibility to adjust activities' rates of production. It allows a smooth and efficient flow of resources, and requires less time and effort to produce than network schedules (Arditi and Albulak 1986).

An early attempt to develop a computer application was made to schedule repetitive-unit construction by Arditi and Psarros (1987). It was limited to solving the basic LOB problem and was not designed to deal with the many implementation-related problems that were later identified. Clearly, there was a need to develop a computerized system that would make use of the principles used by Arditi and Psarros (1987) but that would also eliminate all of the associated shortcomings. A computer program that can easily and effectively be used by contractors could improve construction productivity significantly. [2]

The Goodyear Company founded the LOB technique in the 1940's and it was then developed by the US Navy in the 1950's. Since then LOB techniques have taken a back Seat and have never been commercialized due to the explosion of systems based on Network Analysis and Critical Path Method (CPM). It should be said that these network and CPM systems have never actually replaced the LOB method; their popularity has simply been due to the unavailability of commercially accessible LOB software. A modified form of the LOB method has been the dominant scheduling technique in Finland since the 1980's.

## 2. RESEARCH OBJECTIVE

The objective of this research study is to study Line of Balance (LOB) method to the project consisting the repetitive activities, as applying LOB the continuous monitoring of the project at each milestone. Using LOB resource allocation and resource leveling is done which gives effective force ratio, which helps in optimizing the resources. Comparison between the cost delay and crashed cost can be done in one schematic diagram related to percentage increase in cost and planned cost. Slope of line is considered in line of balance scheduling, which indicates the rate of production of each activity, by which the monitoring process become easy. The increased in slope shows the higher rate of production, whereas the decreased in slope shows slow rate of production. Crashing of activity can be done to reduce the duration of activity. VICO software is used for the identification of the total duration required by project for its completion and comparison with actual plan by using line of balance method and VICO software, and find out the float in project and representing the project with the use of flow line chart for repetitive nature of activities.

### 2.1 Comparison between bar charts and Line of Balance Technique.

- Bar chart facilitates focusing attention on specific objective, whereas LOB defines the objectives related to production rate, where monitoring is easy at any stage of project.
- In Bar chart, the result of planning activities can be clearly seen, where in LOB the results is carried out on reference with resource allocation and optimization.
- Activities on the critical and those with float can be easily identified, In LOB buffer are provided at start or end of activities, this facilitates the crashing operation.

### 2.2 Advantages of Line of Balance method

- The use of graphic and the visual intuitiveness provided by the separate activity types enables project manager, schedulers, owners, and construction personnel to better visualize the plan of action and more easily communicate the plan to everyone involved within the project.
- Benefits of this method allows the planner to plan a feasible schedule that is not sensitive to disturbances. The main advantage of LOB in scheduling projects is that it can convey important production information (eg. Work location, progress direction, and production rate) in an easy-to-visual graphic format.

### 3. METHODOLOGY

Following are the steps adopted for drawing LOB graphs for scheduling of high-rise building:

**3.1 Data Collection:** In high-rise residential building, number of activities is carried out like brickwork, plastering, plumbing, electrification, etc. on each unit, and same activities are repeated from one floor to another. For drawing LOB graphs, such repetitive activities and duration of each activity was collected. Also, to draw the histogram and to calculate activity progress rate, EFR and IFR, number of labours associated for each activity was collected in detail from the respective site.

**3.2 Drawing LOB diagram:** Once the data have arranged in tabular form like activity symbol, planned and actual duration, number of labours, the next step is to draw the LOB graphs for all the repetitive activities with planned duration and actual duration for all the floors. The graphs were drawn by taking duration in days on X- axis and number of floors on Y-axis, and the total duration required for all the repetitive activities was known from the same graph. These graphs are drawn by giving buffer before starts each activity because, when construction activities progress continuously in a chain, some spacing between activities is required. This spacing serves as a buffer and may be a required stage or time interval, which usually referred to as stage and time buffers. When rate of production is more, buffer is to be provided at top, and when the rate of production is less, buffer is to be provided at bottom.

### 3.3 Formula for calculate crew size:

Calculation for activity

1. Theoretical Gang Size at Chosen output rate (G)  
 $G = (R \times \text{Man hour per unit}) / (\text{No. of working hour per man per week})$   
 $G = (2 \times 600) / (6 \times 8)$   
 $G = 25$
2. Actual Gang Size (Ga)  
 $G_a = \text{Actual gang size}$   
 $G_a = 25$
3. Actual Rate of output (Ra)  
 $R_a = R \times (G_a / G)$   
 $R_a = 2 \times (25 / 25)$   
 $R_a = 2$
4. Actual Duration for one unit (D)  
 $D = (\text{Man hour per unit}) / (\text{No. of Man per Gang} \times \text{No. of working hours per man per day})$   
 $D = 600 / (38 \times 8)$   
 $D = 1.97$   
 Number of working hours per day = 8 Hours
5. Time from start on first unit to start on last unit (T)  
 $T = (n - 1) \times \text{No. of working days per week} / R_a$   
 $T = (21 - 1) \times 6 / 2.2$   
 $T = 54.54$   
 $n = \text{total number of repetition}$   
 $n = 21$

Table 1: Calculation for LOB

Activity	Duration (days)	Start Date	Finish Date	Avg. Labours per day	Working Hours	Total Working Hours	Theoretical Gang Size (G)	Actual Gang Size (Ga)	Actual Output Rate (Ra)	Actual duration for one unit (D)	Time from Start on first unit to start on last unit (T)	Buffer (B)
D - 3rd - 4th Column & N. S. Walls Reinforcement	3	Fri 12/08/16	Wed 17/08/16	25	8	600	25.00	25	2.0	3.0	60.0	0
D - 3rd - 4th Columns & N. S. Walls Elec & Plumbing Conducing	3	Fri 12/08/16	Wed 17/08/16	7	8	168	7.00	7	2.0	3.0	60.0	0
D - 3rd - 4th Column & N. S. Walls Shuttering	3	Sat 13/08/16	Thu 18/08/16	40	8	960	40.00	32	1.6	3.8	75.0	0
D - 4th Slab Beam Bottom	3	Sat 13/08/16	Thu 18/08/16	20	8	480	20.00	20	2.0	3.0	60.0	0
D - 4th Slab Shuttering	3	Sat 13/08/16	Thu 18/08/16	20	8	480	20.00	20	2.0	3.0	60.0	0
D - 4th Slab Beam Reinforcement	3	Tue 16/08/16	Fri 19/08/16	13	8	312	13.00	15	2.3	2.6	52.0	0
D - 4th Slab Reinforcement	3	Tue 16/08/16	Fri 19/08/16	13	8	312	13.00	15	2.3	2.6	52.0	0
D - 4th Slabs Elec & Plumbing Conducing	3	Tue 16/08/16	Fri 19/08/16	7	8	168	7.00	7	2.0	3.0	60.0	0
D - 4th Slab Beam outer Sides	3	Tue 16/08/16	Fri 19/08/16	6	8	144	6.00	6	2.0	3.0	60.0	0
D - 4th Slab Outer Sides	3	Tue 16/08/16	Fri 19/08/16	5	8	120	5.00	5	2.0	3.0	60.0	0

D - Columns + NS + 4th Slab beams (M-30) and 4th Slab RMRCC (M-30) Grade	1	Fri 19/08/16	Sat 20/08/16	15	8	120	5.00	15	6.0	1.0	20.0	0
D - 4th Slab Aluform Centering & Shuttering	1	Sat 20/08/16	Wed 24/08/16	40	8	320	13.33	38	5.7	1.1	21.1	10

Following data is taken from case study conducted from Aluform construction site, data is formulated by Line of Balance formula.

**3.4 Histogram:** The resources, especially in case of manpower, are limited and it is necessary that the person in-charge of execution or the manager has to prepare a resource analysis report which may enable him to put to best use of manpower resource at his hand. There will be peaks and valleys in the form of required resources in any project and the manager can try to level out these peaks and valleys with the help of resource analysis report. A graph is plotted for the requirement of resource against the period of requirement and this is known as Resource Usage Profile or in general in the language of statistics a Histogram. It is a bar graph of raw data that creates a picture of the data distribution. In this case Histogram will show what is the maximum and minimum number of labours required for a given period of the activity.

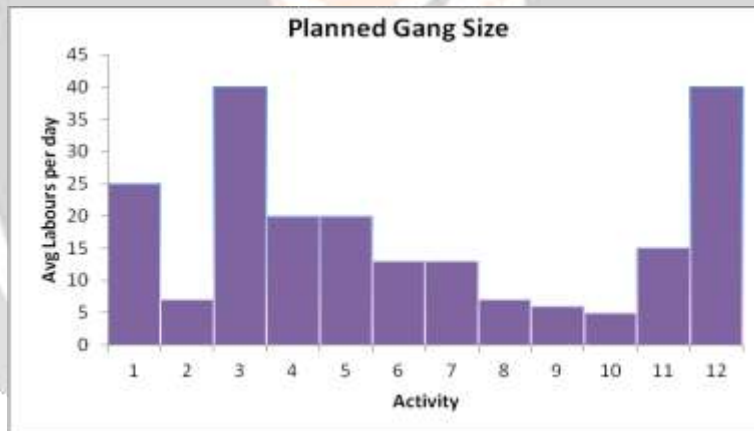


Fig.4.1 Histogram for planned gang size

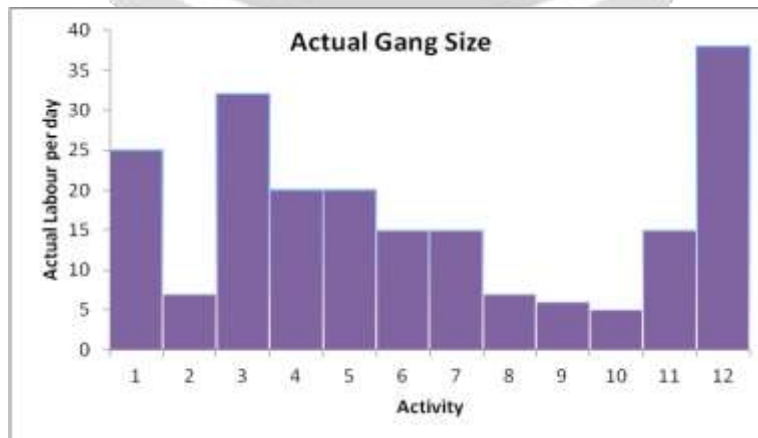


Fig.4.2 Histogram for actual gang size



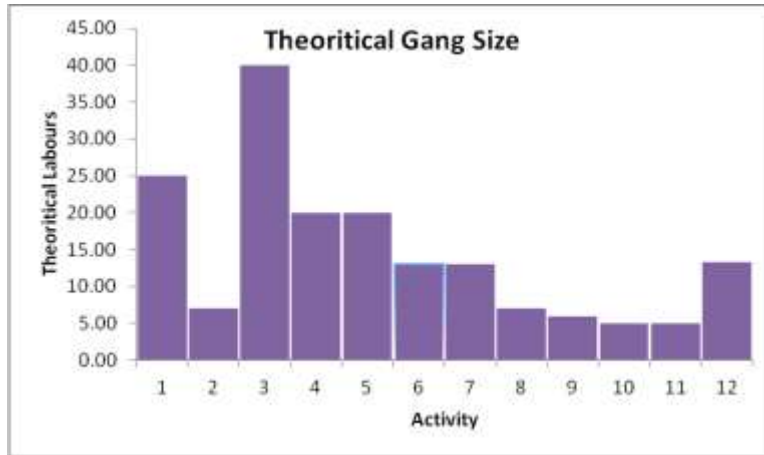


Fig.4.3 Histogram for theoretical gang size

**3.5 Flow Lines using VICO Control Software:**

VICO software facilitates to draw flow line view with Gantt chart. VICO gives flow lines views which is good in visualization, Gantt chart lacks in showing as it consist of bar chart and difficult to view. VICO flow lines view shows start and end duration with date which can be visualize easily. Both views helps in planning and scheduling project effective way. Buffers can be easily seen in VICO Control flow line view as shown in Figure.

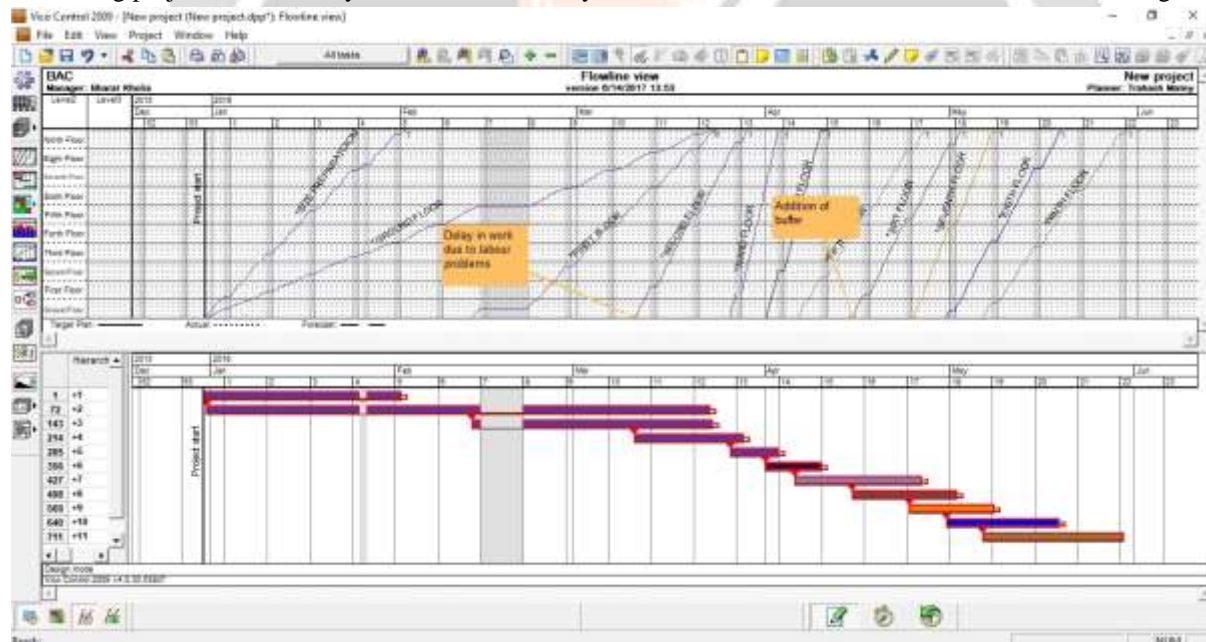


Fig.4.4 Flow lines with Gantt chart view using VICO Control Software

**4. CASE STUDY**

The Line balance method (LOB) is implemented on data collection shown in table 1 and Rate of production i.e. efficiency is calculated which will help in drawing the flow line of project progress. In MIVAN formwork construction for high-rise building consists of repetitive sets of activities. As an example the activity progress rate for actual duration is calculated and shown in table 1. Likewise activity progress rate will be calculated for actual duration and further scheduling process of residential building will be carried out.

## 5. RESULT

- 1) Line of balance method is effective in finding out rate of production of each activity using crew size.
- 2) Increase in labours increases the project production rate but increase of labours cause increase in cost.
- 3) Implementation of VICO Control 2009 software helps in planning and visualizing in effective way in planning and scheduling of activities in each location.
- 4) Activity rate can be compared which is calculated from line of balance formula.
- 5) Resources required i.e. labours required can be calculated from formula which gives theoretical and actual results.

Table 6.1: Results for Gang size

Activity	Planned Labours per day	Actual Gang Size (Ga)	Theoretical Gang Size (G)
D - 3rd - 4th Column & N. S. Walls Reinforcement	25	25	25
D - 3rd - 4th Columns & N. S. Walls Elec & Plumbing Conduiting	7	7	7
D - 3rd - 4th Column & N. S. Walls Shuttering	40	32	40
D - 4th Slab Beam Bottom	20	20	20
D - 4th Slab Shuttering	20	20	20
D - 4th Slab Beam Reinforcement	13	15	13
D - 4th Slab Reinforcement	13	15	13
D - 4th Slabs Elec & Plumbing Conduiting	7	7	7
D - 4th Slab Beam outer Sides	6	6	6
D - 4th Slab Outer Sides	5	5	5
D - Columns + NS + 4th Slab beams (M-30) and 4th Slab RMRCC (M-30) Grade	15	15	5
D - 4th Slab Aluform Centering & Shuttering	40	38	13.33

## 6. CONCLUSION

In this research, the objective is to study and implement the LOB method and VICO control tool for the calculations of total project duration of high rise residential building. According to the result the better method for

the scheduling of project will be selected from LOB and VICO tool for the calculation of flow line of project progress. LOB method and VICO tool are a graphical representation of repetitive activities where project manager can compare the planned and actual rate of production by which project manager can take suitable action over progress.

## 5. REFERENCES

- [1] David Arditi, Onur B. Tokdemir and Kangsuk Suh (2001), "Scheduling system for repetitive unit construction using line-of-balance technology", *Engineering construction and architectural management* 2001 8/2,90-103.
- [2] David Arditi, Onur B. Tokdemir and Kangsuk Suh (2013), "Challenges in Line of balance scheduling" *J. Constr. Eng. Manage.* 2002.128.545-556.
- [3] Robert b. Harris, Photios G. Ioannou (2014), "Scheduling projects with repeating activities", *J. Constr. Eng. Manage.* 1998.124.269-278.
- [4] Mohammad A. Ammar, "LOB and CPM Integrated Method for scheduling repetitive projects", *Journal of Construction Engineering and Management*, Vol. 139, No.1, Jan(2013)
- [5] Magdalena Rogalska, and Zdzislaw Hejducki, "Time Buffers in Construction Process Scheduling", *The Journal of Civil engineering and Management*, Vol. XIII.
- [6] Recardo Mendes Jr. and Luis Fernando M. Heineck, (98), "Preolanning Method of multi-story building construction using line of balance", *Precedding IGLC 98*.
- [7] Sherif Mohamed Hafez, (2004), "Practical limitations of line of balance in scheduling repetitive construction units", *The Alexandria Engineering Journal*, Vol. 43, No. 5.
- [8] I-Tung Yang and Photios G. Ioannou, "Resource-Driven scheduling for repetitive projects: A Pull-System Approach"
- [9] K.K. Chitkara, *Construction Project Management*, pp (205-210)
- [10] Hamid Reza Zoifaghar Dolabi and Abbas Afshar, "Deadline constraint satisfaction in the Line-of-Balance scheduling method for resource constrained project with non serial activities" *Const. Research Congress 2016*