Journal Paper: Application of Line of Balance Scheduling Technique (LOBST) for a Real estate sector

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ABSTRACT:
This paper reports one aspect of a Repetitive Scheduling Method (RSM) or Line Of Balance Scheduling Technique (LOBST) applied for a housing project having project activities repetitive in nature. Linear scheduling methods are planning and scheduling techniques mostly used in construction and manufacturing industries where repetitive operations are abundant. The Line-Of-Balance Scheduling Technique (LOBST) is a linear scheduling method that allows the balancing of the operations such that each activity is continuously and efficiently performed in each consecutive unit. Some construction projects that involve sets of tasks organized in repeating sequences are similar to continuous manufacturing processes in their structure. The basic concepts of LOBST have been applied in the construction industry as a planning and scheduling method. Examples of such projects include pavement construction, multihousing projects, and high rise building construction. Today, LOB application has been further expanded, making it suitable for a whole spectrum of activities ranging from research and development through job-shop and process flow operations.

KEY WORDS
Construction planning, lean construction, line of balance, Repetitive scheduling.

INTRODUCTION:
LOBST was first applied to industrial manufacturing and production control, where the objective was to attain or evaluate a production line flow rate of finished products. The LOB 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. LOB has not been fully developed and implemented by the U.S. construction industry because of the immense popularity of network techniques including CPM. LOB has been applied to resource scheduling and coordination of subcontractors, to a highway pavement construction project, to modeling production activities for multi-facility projects, and to transportation projects.

In the context of construction projects, the LOB technique offers following advantages:

- It allows project managers to see, in the middle of a project, whether they can meet the schedule if they continue working as they have been.

- It exposes process bottlenecks, allowing the project manager to focus on those points responsible for slippage.
It helps avoiding many hiring and procurement problems in issues pertaining to the flow of labor and material used during construction.

LOB scheduling has the capability to ensure a smooth procession of crews from unit to unit with minimal conflicts and decrease idle time for workers and equipment.

We use line balancing technique to achieve:
1. The minimization of the number of workstations;
2. The minimization of cycle time;
3. The maximization of workload smoothness;
4. The maximization of work relatedness.

**Advantage of LOBST over CPM technique**

Linear Scheduling is composed of continuous activities, unlike CPM which is composed of discrete activities. Most construction projects are scheduled based on some sort of critical path planning method (CPM). A number of versions of this technique have been developed and is used as the basis for many of the popular project management software packages. Many researchers discussed the suitability of CPM for construction projects, mainly those repetitive projects, such as railroads and multi-story buildings, and more recently for the lean construction concepts. As more complex becomes the project more complex it will be this network approach. Usually such master schedules cannot be accurately detailed too far into the future because of lack of information about actual duration and deliveries. Other important disadvantage relies on the main idea of the CPM method which is focused on finding the path which is critical. The schedule is developed based on this premise and the resource capacity and material requirements are input for the project simulation. The emphasis is on project duration shortage and resource leveling. The fact of having a “critical path” implies having non critical ones, which have float time. It means that the planning construction incorporates wastes what significantly diverts from a modern construction philosophy. The CPM is ineffective and cumbersome for scheduling linear continuous projects but extremely efficient for more complex and discrete type projects.

The LOB technique is very suitable for repetitive projects like residential buildings; however it may be adapted for non-repetitive projects as well. The main advantages of LOB schedule are its graphical presentation, easy understanding of the schedule and the goals of planning used in it. The research conducted by the authors aims to improve the LOB concepts on building construction and prove its usefulness.

LOB is superior than CPM in its higher compatibility with Building Information Modeling and 3D models. As a visualization tool, it is easier to read a Line of Balance schedule, once you understand how the lines go. Furthermore, as far as setup, for me, Line of Balance seems to be a much simpler way to schedule large amounts of activities, when compared to the Gantt chart schedule on a Primavera program. With a LOB schedule you don’t have to replicate that activity every time. That decreases the amounts of pages needed for presentation of a certain sequence of repeated activities from 4 or 5 pages in a Gantt chart to just 1 page on a Line of Balance schedule.
Disadvantages of LOBST Technique

- Inability to generate a clear critical path of the project schedule, relative to the one provided by CPM schedules. Could only be divided by location.
- 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.

LITERATURE REVIEW:

The LOBST is based on the underlying assumption that the rate of production for an activity is uniform. In other words, the production rate of an activity is linear where time is plotted on one axis, usually horizontal, and units or stages of an activity on the vertical axis. The production rate of an activity is the slope of the production line and is expressed in terms of units per time. LOB scheduling can be performed more efficiently when the concept of line-of-balance is combined with network technology. Usually, a network diagram for one of the many units to be produced is prepared and incorporated into the LOB schedule. The LOB method manipulates worker-hour estimates and the optimum sizes of crews to generate the LOB diagram. Worker-hour estimates and optimum crew sizes are usually obtained through direct interaction with a scheduler, the site manager, or related subcontractors who are knowledgeable enough to reflect the actual conditions of a project and of its constituent activities. Once the number of crews and the expected rate of output have been computed for each activity, the LOB diagram can be plotted. The number of units to be produced is plotted against time. Two oblique and parallel lines, whose slope is equal to the actual rate of output will denote the start and finish times respectively of each activity in all the units from the first to the last.

LOB software development:

An attempt to develop a computer application was made by “Psarros” in 1987. It was limited to solve the basic LOB problem and was not designed to deal with the many implementation-related problems. This application called “SYRUS”: A System for Repetitive Unit Scheduling, it was a pioneering attempt to prove that a computer program can be developed but was not free from flaws.

The second generation of computer programs was developed by “Suh” in 1993 and is called “RUSS”. The system has an analysis program written in "C" language. The input that consists of several types of initial information is obtained from the user. The program analyzes a "unit network" that represents the logical relationship among activities performed in one of the many identical units and calculates the production rate of each activity taking maximum productivity and learning effect into consideration. “CHRISS” is a computerized system to schedule high-rise building construction, is developed by using the line-of-balance technology assisted by an expert system. The development of CHRISS provides the opportunity for a novice
planner to easily generate a construction schedule for a high-rise building project. This can be achieved by CHRISS thanks to the knowledge embedded in the expert system module called LOBEX.

**RESEARCH & METHODOLOGY:**

Line of balance is a method of showing the repetitive work that may exist in a project program as a single line on a graph rather than a series of individual activities on a bar chart. A Line of Balance Chart can be used for any project where there are a number of separate but common activities to undertake or an activity with a long duration. They are not well suited to individual activities that have a short duration that are undertaken in isolation to similar activities in a project.

A typical project where this may exist is a HOUSING PROJECT consisting of several houses where the same type of work such as foundations, brickwork, roof construction, and internal trades are undertaken on each house. If these activities are programmed using a conventional bar chart it would look like the example in the Fig 1. However, if the same operation was to be programmed using the Line of Balance method it would look like Fig 2. As can be seen the difference between the two methods is a Line of Balance Chart can summarize a group of similar activities onto one line and consequently a large number of common activities onto a much smaller document.

Unlike a Bar Chart, which shows the duration of a particular activity, a Line of Balance Chart shows the rate at which the work that makes up all of the activities has to be undertaken to stay on schedule, the broad relationship of one group of activities to the subsequent group and if one group is running behind schedule, it will impact on the following group. In this respect, a Line of Balance Chart does not show direct relationships between individual activities; it shows an output relationship between the different operations in that one operation must be completed at a particular rate for the subsequent relationship to proceed at the required rate.

Fig. 2 has the ‘x’ axis as time and the ‘y’ axis as the number of units. However, a Line of Balance Chart can be produced using units of work, linear meters, m2 and m3 or even all three on the ‘y’ axis, each one for a different operation. In this respect excavation can be plotted showing the planned quantity of spoil excavated per day, piling can be plotted showing the number of piles to be constructed per day, concrete foundations and superstructures can be plotted showing the number of pours to be completed per week. Even Mechanical and Electrical works can be plotted on a Line of Balance Chart by showing the meter lengths of cable tray, pipe work and cable to be installed per day or per week. There are no hard and fast rules to producing a Line of Balance Chart for a project and as with all the methods in project planning it takes practice to develop the expertise. To produce a Line of Balance Chart a program should be developed in the normal fashion as a CPA, then a bar chart and then coded so that common operations can be selected as a group.
LOBST- project Schedule Development

Line of Balance (LOB) is a management control process for collecting, measuring and presenting facts relating to time (see Schedule Control), cost and accomplishment - all measured against a specific plan. It shows the process, status, background, timing and phasing of the project activities, thus providing management with measuring tools that help:

1. Comparing actual progress with a formal objective plan.
2. Examining only the deviations from established plans, and gauging their degree of severity with respect to the remainder of the project.
3. Receiving timely information concerning trouble areas and indicating areas where appropriate corrective action is required.

The "Line of Balance" itself is a graphic device that enables a manager to see at a single glance which activities of an operation are "in balance" - i.e., whether those which should have been completed at the time of the review actually are completed and whether any activities scheduled for future completion are lagging behind schedule. The LOB chart comprises only one feature of the whole philosophy which includes numerous danger signal controls for all the various levels of management concerned.

To do LOB, the following is needed:

1. A contract schedule, or objective chart;
2. A production plan or lead-time chart for the production process itself;
3. Control points cumulative inventories; and
4. A program status chart on which to plot LOB and the cumulative quantities of units that have passed through the control points of the assembly/production process.
Example: Line of Balance. Figure 4

Remember that the shape of the LOB will change over time, especially if the production process has a beginning and an end. Remember, too, that LOB charts show where a problem is, but not necessarily why the problem exists or what the solution is.
FINDINGS & DISCUSSION:
When a group of activities are extracted from a program in this manner it can be seen how these common activities are grouped and over what duration they are planned to be carried out. Then, the quantities that each activity on the bar chart for the operation in question represents are established, aggregated against time and plotted as a line on the Line of Balance Chart. The Line of Balance Chart shown in Fig. 2 shows the ideal situation as all of the operations listed show the rate at which work is achieved as uniform. This usually means the resources required will also be constant and is the ideal scenario. It is much easier to manage the different operations of a project where there is a common and uniform output required and a steady level of resources. However, when a number of similar activities are extracted as a group and then converted into a Line of Balance Chart it is not unusual to see that the rate at which the work has to be carried out is erratic. Consequently the fluctuation in the resources required is similarly erratic. In practice this is untenable. It is very difficult to increase and decrease resources quickly and regularly.

Resource leveling can greatly assist this situation although it can be found that even after resource leveling is undertaken the outputs and there sources required will still be erratic. In such circumstances it is not unusual for a Line of Balance chart to be produced from a program and then find it is advantageous to modify the program, even after resource leveling has been implemented, to achieve a steady output. Often, producing a Line of Balance Chart can be a more effective and an easier method in which to resource level a project. A Line of Balance Chart is progressed by plotting on the chart the work achieved. The planned rate of completion of the various trades can then be compared with the actual. Based on the rate at which the work has been achieved the likely completion date can be extrapolated to establish the likely completion date. If the rate at which the work is being achieved is lower than required, adjustments are made to increase the output. For example, the Line of Balance Chart in Fig. 3 has been updated up to week 12 of the project. It can be seen that that the Foundations are on schedule and almost complete but Brickwork and Roof Construction are running behind schedule. The Internal Works have not started but the anticipated rate of work has been plotted on the chart and by extrapolation the first unit will be completed 3 weeks late. This delay can be corrected by increasing the output for the Brickwork and Roof Construction and the Internal Works by either taking measures to increase efficiency or increasing the resources committed to the operation that is not achieving the correct output.

LOB in 4D CAD:
With advancements in the fields of Building Information Modeling (BIM) and Virtual Construction, the techniques and technologies used in scheduling construction projects have also evolved. The development of 4D Models has been one of the major advancements in the field of construction scheduling. “4D Modeling is a process/method in which 3D CAD models are visualized in a 4-dimensional environment.”

Typically, 4D CAD models are created by linking building components from 3D CAD models with activities extracted from a CPM schedule. One of the advantages of 4D modeling is
that it provides the user with a clear and direct picture of the schedule. Its basic goal is the time-lapse visualization of a construction process by association of components and CPM schedule activities." This visual representation of the schedule helps to quickly and clearly communicate this schedule to different stakeholders in a project. Simulating and analyzing what-if scenarios before commencing work on site is another useful advantage allowed by 4D modeling.

Activity based planning, like CPM scheduling has been the dominant scheduling technique for 4D Modeling. There are numerous disadvantages to utilizing activity based planning for 4D Modelling. The difficulty of applying flow-based thinking in such models arises from the problem that the models are based around discrete activities. An additional problem is the fact that 4D CAD models often are not organized according to a location-based logic, which further constrains the application of flow-based thinking." Because the basis of 4D Modeling is "on CPM networks and input 3D geometry it limits utilization for operations planning. It carries over some limitations of CPM; it assumes the production rate is constant for the duration of an activity, and it does not capture or visualize the reasons behind an existing plan or any geometric planning parameters, such as workflow directions."

LOB scheduling offers solutions to various compatibility difficulties between 3D Cad models and construction project schedules. Location-based scheduling provides a promising alternative to activity-based planning approaches for planning of work-flow with 4D CAD. A location-based approach to 4D CAD could also improve the usability of the 4D CAD models for work-flow analyses. 4D Modeling and location based scheduling complement each other and reinforce the various intrinsic benefits they possess individually. The combination of location-based planning by applying the Line-of-Balance technique in combination with 4D CAD could be a promising method in which the strengths of both methods could reinforce each other.
CONCLUSION:

The LOB technique is very suitable for repetitive projects like residential buildings; however it may be adapted for non-repetitive projects as well. The main advantages of LOB schedule are its graphical presentation, easy understanding of the schedule and the goals of planning used in it. The research conducted by the authors aims to improve the LOB concepts on building construction and prove its usefulness. A Line of Balance chart should not be submitted as a Tender or an Accepted Program. If it is submitted it is unlikely that it would be accepted anyway; it does not show exact relationships between individual activities in the same way as a Bar Chart does. However, subcontractors should always be expected to produce a Line of Balance Chart for their works as part of their program information. A subcontractor’s program has to be sufficiently detailed to show production rates anyway and should lend itself to being converted into a Line of Balance Chart.

There are very few projects where a Line of Balance Chart cannot be used and be of benefit. It is only small subcontracts where the activities are scattered across the duration of a project that a Line of Balance will not be useful; for all important subcontracts it will assist the management of the subcontract and the project. They are usually much easier to read than a detailed Bar Chart and a subcontractor should always provide them as part of their progress reports. There is also every reason why the subcontractor’s Line of Balance Charts should be included in a progress report, particularly if a subcontract is falling behind schedule. A further benefit of producing a Line of Balance Chart is the essence of such a document is output and productivity. In this respect it is not unusual for claims to be produced by subcontractors when the works are completed citing events for which the employer, in the case of a subcontractor is held responsible. The claims are usually for delay and disruption.

By disruption it is meant that an activity or activities achieved lower than planned output and efficiency because of unforeseen circumstances for which others are responsible. Examples of disruption are; where design information was provided in a piecemeal or uncoordinated fashion, or where the resources deployed had to be continually moved from one work area to another or where there are continual variations instructed. The consequence of the alleged disruption being that the operation in question could not achieve its planned output and productivity and it cost the subcontractor more and took longer than if the events and circumstances had not occurred. Retrospective disruption claims are difficult to advance with any great certainty of success. They always beg the question why were the disruptive issues not identified and quantified at the time the low productivity was taking place. There is also the difficulty of proving that the output and efficiency of the operation would have been as productive as planned but for the disruptive events. However, if a Line of Balance Chart is produced contemporaneously it would identify the low output and productivity enabling the causes to be addressed at the time. And, if there is genuinely a case to be made for disruption a Line of Balance Chart showing the lower output and productivity is a very good way of demonstrating it.
The study shows that there are numerous intrinsic advantages and benefits for applying Line of Balance scheduling in construction projects. The availability of supporting software programs help realize these benefits. Furthermore, LOB could play a major role in facilitating the implementation of Building Information Modeling technologies. The research shows that there is great potential for Line of Balance scheduling in the construction industry, and in the future there is a good chance that it would be implemented in more construction projects. With the developing and upgrading of Line of Balance software programs, and construction related academic programs integrating the LOB scheduling technique in their curriculums, the acceptance and utilization of Line of Balance is expected to increase significantly.
References:


Appendix:

Fig 1

House Construction Programme

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<tr>
<th>ID</th>
<th>Task Name</th>
<th>Duration</th>
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<tbody>
<tr>
<td>1</td>
<td>House 1</td>
<td>70 days</td>
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<tr>
<td>2</td>
<td>Foundations</td>
<td>10 days</td>
</tr>
<tr>
<td>3</td>
<td>Brickwork</td>
<td>25 days</td>
</tr>
<tr>
<td>4</td>
<td>Roof Construction</td>
<td>15 days</td>
</tr>
<tr>
<td>5</td>
<td>Internal Works</td>
<td>20 days</td>
</tr>
<tr>
<td>6</td>
<td>House 2</td>
<td>70 days</td>
</tr>
<tr>
<td>7</td>
<td>Foundations</td>
<td>10 days</td>
</tr>
<tr>
<td>8</td>
<td>Brickwork</td>
<td>25 days</td>
</tr>
<tr>
<td>9</td>
<td>Roof Construction</td>
<td>15 days</td>
</tr>
<tr>
<td>10</td>
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<td>20 days</td>
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<tr>
<td>11</td>
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<tr>
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<td>25 days</td>
</tr>
<tr>
<td>14</td>
<td>Roof Construction</td>
<td>15 days</td>
</tr>
<tr>
<td>15</td>
<td>Internal Works</td>
<td>20 days</td>
</tr>
<tr>
<td>16</td>
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<td>18</td>
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<td>25 days</td>
</tr>
<tr>
<td>19</td>
<td>Roof Construction</td>
<td>15 days</td>
</tr>
<tr>
<td>20</td>
<td>Internal Works</td>
<td>20 days</td>
</tr>
</tbody>
</table>

Fig 2

House Construction

- Foundations
- Brickwork
- Roof Construction
- Internal Works
Fig 3

House Construction Line of Balance

- Actual
- Projected
- Projected completion to first unit 3 weeks behind schedule

Weeks
0  5  10  15  20

Units
0  1  2  3  4

Time Now

Flasillage
Blockwork
Roof Construction
Internal Works

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