Line Of Balance

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Intended Learning Outcomes

• Define the principles of Line of Balance (LOB)
• Demonstrate the application of LOB
• Understand the importance of LOB
• Understand the process of applying LOB
Location Based Management

• LBM is a production control system that integrates planning, scheduling, and control.

• Tasks are defined by production rates, resource consumption and quantities.

• The placement and interrelated dependencies of tasks are defined by technical dependencies, locations, and continuity requirements.
Location Based Management

- Is a scheduling and control technique that is believed to offer advantages in building construction compared with CPM and PERT.

- LBM includes important aspects that are omitted in CPM and PERT such as continuous work flow and location constraints.
Location Based Management

• LBM combines production rates, quantities, and resource consumption in specific locations to estimate the duration of tasks.

• In LBM, similar activities are collected in tasks and displayed as a single line (production lines or flow lines) over multiple locations.
Location Based Management

The result allows *schedulers and managers* to evaluate whether construction *crews* can perform their work *undisturbed* by *aligning rates of production*. 
Activity-based versus location-based scheduling and control
Construction scheduling and control is divided into **two** main methodologies:

- **Activity-based** and **Location-based**.
- **Activity-based** methods include The critical path method (**CPM**) and the program evaluation and review technique (**PERT**).
- **Activity-based** methods depend solely on technical relationships between activities in the schedules governed by technical constraints.

• **Activity-based** methods highlight the activities that should be considered **critical**
Activity-based methods criticism

• Do not include any algorithm, calculation, or consideration for solving the *practical organization problems* of the on-site production process.

• The assumptions that *unlimited resources* are available and that *personnel can be hired and fired* freely are erroneous.
Activity-based methods criticism

• Were never intended for projects that are sensitive to resource limitations and continuous workflow because the methods originated in the aerospace and military industries.

• Lacking work continuity and learning effects
Activity-based methods criticism

• Does not contain elements that ensure a smooth procession of crews from unit (Location) to unit with no conflict and no idle time for workers and equipment.

• Difficult to manage on repetitive projects, due to discrete management of similar activities in different locations.
Activity-based methods criticism

• Many attempts to solve the short comings of the original CPM and PERT techniques:
  • Resource leveling
  • Optimization of cost and time relationships.
  • Communicative abilities of CPM addressed by linking CPM schedules with 3D modeling of building components.
• Improving health and safety procedures and flow optimization through lean construction principles.
location-based methods

Contains numerous methods that only differ slightly from modern LBM. These include:

- line of balance scheduling,
- linear scheduling method,
- vertical production method,
- Repetitive project model,
- velocity diagrams,
- time space scheduling,
- Construction planning technique,
- time Location Matrix Model,
- disturbance scheduling
- horizontal and Vertical logic scheduling
Activity Based Schedule (CPM)

Location Based Schedule

No activities

Many activities
Location Based Management

Working at the same time and in the same location negatively affects the work of construction crews because technical constraints are not respected.
Location Based Management

The location-based schedule illustrates areas not utilized for production, allowing the project manager to exploit vacant areas of the build site by moving work crews to those locations.
Location Based Management

The location-based schedule illustrates productivity problems. The flow lines reveal tasks that are completed at a comparatively slower rate, which not only affects a project’s lead-time; it can also result in discontinuous production.
Location Based Management

Location

Time

High productivity rate

Low productivity rate
Line of Balance (LOB)

• Definition
  A simple diagram to show location and time at which a certain crew will be working on a given operation.
  ➢ Is a **Good Visual tool** that lets us see if a construction program can be achieved with the minimum waiting time between tasks
Line of Balance (LOB)

• Is a scheduling methodology to optimize resources used.
• Resources are used to balance out tasks by adding additional crews to slower tasks.
• The fully aligned schedules contain no float.
Line of Balance (LOB)

• Is primarily used on projects that have repeated elements like Highways, Pipelines, High-rise buildings, hotel bedrooms, bridge etc.
Benefits of LOB

- Continuous resource use
- Less starts and stops
- Crews will develop a learning momentum
- Improve productivity by 20%
- Save **money** and **time**
- Faster scheduling process
- Good Visual control
Activity-based VS Location-based
Activity-based

• 30 floors, 4 activities in each location = 120 activities
• Formwork-reinforcement-pouring on the same floor = 60 links
• Pouring – formwork next floor = 29 links
• Pouring – finishes two floors below = 28 links
• Internal links in finishes to prevent resource overlapping = 29 links
• **Total: 120 CPM activities, 266 links**
Activity-based

Formwork Floor 3 → Reinforcement Floor 3 → Pouring Conc. Floor 3 → Finishing Floor 3

Formwork Floor 2 → Reinforcement Floor 2 → Pouring Conc. Floor 2 → Finishing Floor 2

Formwork Floor 1 → Reinforcement Floor 1 → Pouring Conc. Floor 1 → Finishing Floor 1
Location-based

• 4 tasks flowing through locations
• 4 links between activities
• 4 links inside activities
• **Total: 4 tasks, 8 link**

➤ **Less tasks**

➤ **Less links**
Location-based
Superior project control

- Easy to interpret
- Clear uncomplicated displays
- Simple to manage
- Easy to monitor
- Effortless progress updates
- Effective control
LOB Calculations

• The objective of using LOB is to achieve a resource-balanced schedule by determining the suitable crew size and number of crews to employ in each repetitive activity.
LOB Calculations

•This is done such that:
  1. the units are delivered with a rate that meets a pre-specified deadline
  2. the logical CPM network of each unit is respected
  3. crews’ work continuity is maintained.
LOB Calculations

• The analysis also involves determining the start and finish times of all activities in all units and the crews’ assignments.
LOB Diagrams

1. Production Diagram

Shows the relationships of the activities for a single unit.
LOB Diagrams

2. Objective Diagram

Used to plot the planned or actual number of units produced vs. time.
3. Progress Diagram

Shows the number of units for which the activity has completed.
Drawing the LOB Schedule

\[ R = \frac{n - 1}{t_f - t_0} \]
Drawing the LOB Schedule

• Similar rates → parallel lines
• Different rates → lines not parallel
• Conflict points → at the last or first unit
LOB Calculations

• The CPM-LOB formulation involve:
  • Crew synchronization
  • Calculating resource needs
  • Drawing the LOB schedule
Crew Synchronization

• A simple relationship between the **duration** taken by a crew in one unit (D) and the **number** of crews (C) to employ in a repetitive activity
Crew Synchronization

• Slope of the shaded triangle in becomes:
  \[ R = \frac{1}{(D / C)} \]
  Then:
  \[ C = D \times R \]
Calculating Resource Needs

• \( Ri = (n - 1) / (T_f - T_0) \)

• \( Ci = Di \times Ri \)

• \( Cai = \text{Round Up} (Ci) \)

• \( Rai = Cai / Di \)
Calculating Resource Needs

![Diagram showing resource needs over time with units and time axes, and labeled arrows for A(5), B(5), C(2), D(5) with TF=3 and C(2) between B(5) and D(5) with TF=3.)
Example

<table>
<thead>
<tr>
<th>Activity</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production rate</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>No of crews</td>
<td>9</td>
<td>30</td>
<td>10</td>
<td>9</td>
<td>2</td>
</tr>
</tbody>
</table>

N=61 units

Required; draw LOB at month 16
Example

• \( R = \frac{1}{(D / C)} \)
• \( D = \frac{C}{R} \)

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<td>2</td>
</tr>
<tr>
<td><strong>Duration</strong></td>
<td>3</td>
<td>6</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>
Example
Example

For A: \( R=3, \ t_0=3, \) 
\[ t_f = 3 + \frac{(61-1)}{3} = 23 \]

For B: \( R=5, \ t_0=6, \) 
\[ t_f = 6 + \frac{(61-1)}{5} = 18 \]

For C: \( RC=RB>RA, \) buffer from top
\[ R=5, \ t_f=23+2=25, \]
\[ t_0=25-\frac{(61-1)}{5}=13 \]

For D: \( R=3, \ t_0=13+3=16, \) 
\[ t_f=16+\frac{(61-1)}{3}=36 \]

For D: \( R=1, \ t_0=16+2=18, \) 
\[ t_f=18+\frac{(61-1)}{1}=78 \]
Example

For A: \( R=3, \ t_0=3, \)

For B: \( R=5, \ t_0=6, \)

For C: \( R=5, \ t_0=13, \)

For D: \( R=3, \ t_0=16, \)

For E: \( x=0 \)

\[
16=3+\frac{x-1}{3}, \quad x=40
\]

\[
16=6+\frac{x-1}{5}, \quad x=51
\]

\[
16=13+\frac{x-1}{5}, \quad x=16
\]

\[
16=16+\frac{x-1}{3}, \quad x=1
\]
Example
Thanks