Lesson 09 – Facilities Layout

The configuration of departments, work centers, and equipment with emphasis on movement of work (product/customers) through the system.

Facilities Layout

Layout decisions are important for 3 basic reasons:

1. Require substantial investments of money and effort
2. Involve long term commitments which make mistakes difficult to overcome
3. They have significant impact on cost and efficiency of short term operations

The Need For Layout Decisions
The Need For Layout Decisions

Improve inefficient operations (e.g. bottlenecks)
Accidents or safety hazards
Minimize material handling costs
Utilize space efficiently
Utilize labor efficiently
Incorporate security measures
Morale problems - facilitate communication and interaction between workers, between workers and their supervisors, or between workers and customers

The Need For Layout Decisions

Reduce manufacturing cycle time or customer service time
Eliminate waste or redundant movement
Promote product and service quality
Encourage proper maintenance activities
Provide a visual control of operations or activities
Facilitate the entry, exit, and placement of material, products, or people
Provide flexibility to adapt to changing conditions
- Changes in volume or mix of outputs
- Changes in methods or equipment
- Changes in design of products/services
- Introduction of new products/services
- Changes in environmental or other legal requirements

Basic Layout Types

Product Layouts - uses standardized processing operations to achieve smooth, rapid, high-volume flow
  - Production/Assembly Line – fixed sequence of production/assembly
  - U-Shaped Layouts – better utilization of labor
### Product Layout Advantages/Disadvantages

**Advantages**
- High rate of output
- Low unit cost – equipment cost spread over many units
- Labor specialization reduces training costs & time
- High utilization of labor and equipment
- Accounting, purchasing & inventory control are more routine

**Disadvantages**
- Repetitive jobs with little advancement - morale issues
- Poorly skilled workers may have little interest in quality
- Inflexible system sometimes susceptible to shutdowns
- Quick repairs require spare-parts inventories & maintenance

### Basic Layout Types

**Process Layouts** – can handle varied processing requirements and usually has departments or other functional groupings where similar kinds of activities are performed

- Equipment is laid out by type rather than manufacturing sequence
- Products/Services move through the system dictated by technical considerations rather than a specified sequence of operations (e.g. hospitals, banks, machine shops, grocery stores, fast food)

### Process Layout Advantages/Disadvantages

**Advantages**
- Can handle a variety of processing requirements
- Not particularly vulnerable to equipment failures
- Generalized equipment is often less costly to maintain
- Individual incentive systems are more successful

**Disadvantages**
- In process inventories can be much higher
- Routing and scheduling are continual challenges
- Equipment utilization rates are much lower - higher unit cost
- Material handling is slow & inefficient and more costly
- Higher supervision costs
Basic Layout Types

**Fixed Position Layouts** – product or project remains stationary, and workers, materials, and equipment are moved as needed.

**Combination Layouts** - can include combinations of product, process and fixed position layouts.

**Cellular Layouts** – groups machines into cells that process products that have similar requirements.

**Product/Process Layouts** – can be converted to more efficient layouts by grouping equipment to do a fixed sequence of processing steps.

**Group Technology**

One worker – several machines.
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Cellular Layout

Basic Layout Types

Service Layouts – deals with locating departments so that the service they provide is the most efficient.
- Warehouse & Storage layouts
- Retail layouts
- Office layouts

Designing Layouts

Designing layouts to meet the many needs/objectives of layout decisions is a very difficult task. Because of the many variables and the number of possible options it is often impossible to do without developing heuristic (intuitive) rules.

<table>
<thead>
<tr>
<th>Frozen Foods</th>
<th>Dry Groceries</th>
<th>Meats</th>
<th>Bread</th>
<th>Check Out</th>
<th>Vegetables</th>
</tr>
</thead>
</table>

How many assignment possibilities are there for these departments and locations?

6! = 6*5*4*3*2*1 = 720 possibilities
Designing Layouts

Precedence diagrams are essential in designing layouts. They show the elemental tasks, times and sequencing of steps in a process.

Designing Layouts

Precedence diagrams identify bottlenecks. Bottlenecks are processes which can not keep pace with their preceding suppliers, thus creating idle time and inefficiency.

The bottleneck in this process can easily be eliminated by building a new rinsing station (parallel task); however the decision must be based on financial considerations! Therefore, it becomes the operations managers responsibility to evaluate alternative solutions (e.g. Can the tasks be assigned in another way to achieve better throughput?).

Designing Layouts

Parallel tasks are very helpful in eliminating bottlenecks.
Designing Layouts

In the previous example we say that the tasks could not be assigned differently to achieve better throughput; however there are many instances where this is not the case.

**Line Balancing** is a procedure which can be used by the operations manager to assign tasks to workstations so that a more even (smoother) work flow can be achieved.

**Difficulties in Line Balancing**

- It may not be feasible to bundle tasks (differences in equipment requirements or non-compatible activities)
- Differences in task lengths can not always be overcome by grouping tasks
- A required technological sequence may prohibit desired task groupings

Assigning Tasks To Workstations

Consider the following 5 tasks. How many workstations are possible?

![Tasks](chart)

- We can assign all of the tasks to 1 Workstation
- We can assign some of the tasks to 1 Workstation and some to another

There are many possibilities! So what do we do?

**Cycle Time (CT)**

Cycle Time (CT) is the maximum time allowed at each workstation to complete its set of tasks on a unit. It establishes the output capacity.

\[ 	ext{Output capacity} = \frac{\text{OT}}{\text{CT}} \]

where \( \text{OT} \) = operating time per day

As a general rule, Cycle Time is determined by Desired Output Capacity (D). Suppose a line operates 8 hours per day (480 minutes) and the Desired Output Capacity is 960 units. What Cycle Time is necessary?

\[ D = \frac{\text{OT}}{\text{CT}} \Rightarrow \text{CT} = \frac{\text{OT}}{D} = \frac{480}{960} = .5 \text{ min} \]
Assigning Tasks To Workstations

Consider the above 5 tasks. If no parallel tasks are introduced calculate the maximum and minimum output capacity for these tasks for an 8 hour (480 minutes) day.

Minimum Output Capacity = \( \frac{OT}{\sum t} = \frac{480}{2.5} = 192 \) units/day

Maximum Output Capacity = \( \frac{OT}{\text{MAX}(t)} = \frac{480}{1.0} = 480 \) units/day

Assigning Tasks To Workstations

The theoretical minimum number (rounded up to the nearest whole number) of workstations necessary to achieve a Desired Output Capacity (D) is given by the following formula.

\[ N_{\text{min}} = \frac{\sum t}{CT} \frac{(D)(\sum t)}{OT} \]

The actual number of workstations necessary to achieve a Desired Output Capacity may be more than the theoretical minimum depending on how efficiently tasks can be grouped into work bundles (e.g. technical skill requirements, incompatible tasks, human factors, and equipment limitations may prohibit tasks from being placed in the same workstation)

Assigning Tasks To Workstations

Consider the above 5 tasks. If no parallel tasks are introduced, and the line operates an 8 hour (480 minutes) day, what is the theoretical minimum number of workstations necessary to achieve a Desired Output Capacity of 480 units per day?

\[ N_{\text{min}} = \frac{\sum t}{CT} \frac{(D)(\sum t)}{OT} = \frac{480(2.5)}{480} = 2.5 \Rightarrow 3 \text{ stations} \]

\[ N_{\text{actual}} = 3 \text{ or more stations} \]
Consider the above 5 tasks.

- How many tasks follow task a? 3
- How many tasks follow task b? 2
- How many tasks follow task c? 2
- How many tasks follow task d? 1

Positional Weight task = task time + ∑(following task times)

<table>
<thead>
<tr>
<th>Task</th>
<th>Positional Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>1.1</td>
</tr>
<tr>
<td>b</td>
<td>1.0</td>
</tr>
<tr>
<td>c</td>
<td>0.7</td>
</tr>
<tr>
<td>d</td>
<td>0.5</td>
</tr>
<tr>
<td>e</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Assigning Tasks To Workstations

Workstation Time Remaining = CT - ∑(task times assigned)

Idle Time = Workstation Time Remaining after assigning all tasks

Percent Idle Time (sometimes referred to as Balance Delay)

PercentIdleTime = \( \frac{\text{IdleTimePerCycle} \times CT}{N_{\text{actual}} \times CT} \) × 100

Efficiency = 100 - Percent Idle Time
**Line Balancing Procedure**

1. Identify *Cycle Time (CT)* and calculate **theoretical minimum number** of workstations.
2. Make assignments to workstations in sequence (left to right) through the precedence diagram.
3. Before each assignment, use the following criteria:
   a. All preceding tasks in the sequence have been assigned
   b. The task time does not exceed the **time remaining**
4. After assignment calculate the **time remaining** where
   \[ \text{time remaining} = CT - \text{sum of times assigned} \]
5. Break ties by using one of the following rules:
   a. Assign the task with the longest time
   b. Assign the task with the greatest number of followers
   c. If there is still a tie choose one arbitrarily
6. Continue until all tasks are assigned

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**Line Balancing - Example**

Example: Arrange the task shown in the diagram above into workstations using the **Line Balancing Procedure**
- Use cycle time of 1.0 minute
- Assign tasks in order of the most number of followers

\[
N_{\text{min}} = \frac{\sum t}{CT} = \frac{2.5\text{min}}{1.0\text{min}} = 2.5 \text{ stations} \quad N_{\text{actual}} = 3
\]
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Line Balancing - Example

Workstation 1
- Task a: 0.1 min
- Task b: 0.7 min

Workstation 2
- Task c: 1.0 min

Workstation 3
- Task d: 0.5 min
- Task e: 2.0 min

Percent Idle Time (Balance Delay) = 16.7%
Efficiency = 83.3%
Other Approaches To Line Balancing

Develop parallel processes to eliminate bottleneck operations (recall the car wash “rinsing” station discussion)

Cross train workers to perform multiple tasks to minimize idle time and assist in bottleneck operations

Develop mixed model lines to handle multiple (similar) products

Note: in practice it is very difficult to achieve perfectly balanced lines. This is not entirely bad because the idle time at a workstation can reduce the impact on brief stoppages and can be used for workers that are not yet up to speed.

Designing Process/Service Layouts

In designing process/service layouts the challenge is to assign departments to locations (e.g. Warehouses, McDonald’s). As we discussed previously, a major obstacle in determining the optimum layout is the large number of possibilities. Unfortunately, no algorithms exist to identify the best possible layout under all circumstances; therefore, operations managers must rely on heuristic (intuitive) rules and trial and error to develop satisfactory solutions.

Some major considerations in designing process/service layouts are:

- Transportation costs for material handling equipment and labor
- Travel time between locations
- Distance between locations
- Initial layout cost
- Effective capacity
- The potential need to redesign the layout

Designing Process/Service Layouts

The information required to design a process/service layout includes the following:

- List of departments with approximate dimensions and dimensions of building(s) that will house the layout
- A projection of work flows between departments
- The distance between locations
- The cost per unit to move "work (loads)" between locations
- The money to be invested in the creation of the layout
- Special considerations such as departments that must be close together or must be separated
Minimizing the distance or transportation costs in moving loads from one location to another is the most common objective in designing process/service layouts.

Distance, costs, and load relationships can be shown between departments and locations by creating a *from-to relationship matrix* for each.

<table>
<thead>
<tr>
<th>Location</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>B</td>
<td>20</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>C</td>
<td>40</td>
<td>30</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Department (Loads)</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
<td>10</td>
<td>90</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>90</td>
<td>70</td>
</tr>
</tbody>
</table>

The distance from A to B = 20; the distance from B to A = 20.
The loads/day from 1 to 2 = 10; the loads/day from 2 to 1 = 20.

We can graphically display the *distance relationship* between the locations by using this schematic.

We can graphically display the *work flow (load) relationship* between the departments by using this schematic.

A *distance-load weighting* can be calculated for the assignment of departments to locations by multiplying the distance relationship by the load relationship. For example: if we assign 1 to A, 2 to B and 3 to C the distance-load between locations can be described by the following schematic.

The *distance-load weighting* for this assignment:

\[ \text{distance-load weighting} = 20 \times 10 + 20 \times 20 + 30 \times 30 + 30 \times 70 + 40 \times 90 + 40 \times 90 = 10,400 \]
So, the problem now becomes one of evaluating all possible assignments of departments to locations. This example is relatively easy since there are only $3! = 6$ assignment possibilities. They are listed below:

<table>
<thead>
<tr>
<th>Locations</th>
<th>Department Assign't</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
</tr>
</tbody>
</table>

Because the number of the small number of assignment possibilities, we can determine the optimum assignment by calculating the distance-load weighting for each alternative. Then select the one with the minimum value.

Obviously this approach is not feasible for large problems. The heuristic (intuitive) rule used in these cases is to assign greatest work flow (load) to closest departments.

Example 3: Using the previously described relationship matrices for Location and Departments, assign the departments (1, 2 and 3) to the locations (A, B, and C) in such a way that the transportation cost (in this case “workload distance”) is minimized. Apply the heuristic assign greatest work flow (load) to closest departments. Template TP06-02 Department Location Assignment Template has been provided to assist with this solution.

Minimizing Transportation Costs - Example

First, enter the Location (Distances) and Department (Loads)
Next, go to the Load Pairs tab and sort the load pairs by clicking the button. This automatically calculates the work flow (loads) between departments and ranks them from greatest to smallest. You see that the work flow is greatest between departments 1 and 3.

Next, go to the Dist Pairs tab and sort the distance pairs by clicking the button. This automatically calculates the distance between departments and ranks them from greatest to smallest. You see that the distance is least between locations a and b.

Minimizing Transportation Costs - Example

This shows that Locations (A, B) are the closest and Department Work Flow is greatest between (1, 3). This means that there are two possible choices:

<table>
<thead>
<tr>
<th>Locations</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Department Assignm't</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Comparing the two assignments one can quickly rule out the second and third possibilities. Therefore the heuristic suggests:

Now, looking at the next closest and the next greatest Work Flow shows that (B, C) and (2, 3) are the second choices. There are two possible choices for assignment in this case:

<table>
<thead>
<tr>
<th>Locations</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Department Assign't</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1</td>
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<td>2</td>
<td>3</td>
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</tr>
<tr>
<td></td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

Comparing the two assignments one can quickly rule out the second and third possibilities. Therefore the heuristic suggests:

Minimizing Transportation Costs - Example

Graphically this option can be displayed as follows:

The distance-load weighting for this assignment = 20x80 + 20x90 + 30x70 + 30x30 + 40x10 + 40x20 = 7,600

This can be automatically calculated by entering the department assignment.
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Homework
- Read and understand all material in the chapter.
- Discussion and Review Questions
- Recreate and understand all classroom examples
- Exercises on chapter web page