**Topic10: Layout Planning**

Overview

The layout planning is an internal arrangement of the conversion facility. It interrelates with the capacity decisions and the processing technology, both of which dictate some spatial requirements on the facility. On the input side of operations requires certain quantities of raw materials to be on hand, stored in appropriate places, to allow subsequent operations to flow smoothly. The locations of other departments must also to be decided. At the output side of conversion, finished storage areas and the conveyance for getting finished products into storage must be considered. These assessment provide some idea of what the layout of production facility is about and its effects on operating costs and effectiveness. Different types of layout designs are applied in different situations.

Learning Outcomes

By the end of this topic, you will be able to:

1. relate the basic layout designs in layout planning.in terms of process-orientated approach, product-oriented design, fixed position design and combination layouts.
2. explain the strategic importance of layout decisions to attain high utilization of space, equipment and people; enhanced flow of information, materials or people; improved employee morale and safer working conditions and flexibility for changes to be possible.
3. ascertain the importance of flexible manufacturing systems for competitive advantage.
4. relate the importance of the flow of products in the product line in terms of line balancing and cycle time.
5. relate other approaches to bring about smooth flow of production in a company.

Introduction

10.1 The basic layout design in the conversion process for the flow of products from the input end to the output end in 4 possible arrangements: process-oriented design, product oriented design, fixed position design sand combination layouts.

10.2 The strategic importance of layout decisions to achieve long run efficiency of the operations for competitive advantage.

10.3 the concept of cellular layouts for the production of similar products.

10.4 Flexible manufacturing systems such as using CIM system bring about flexibility in production , improves quality, reduce indirect labour costs and meeting customer needs.

10.5 service layout is more towards using process layouts because of variability in customer processing requirements as seen in hospitals, banks and other financial institutions, service centres, super markets, department stores and retailing outlets.

10.6 Product layout designs to bring about the efficient flow of products and this is known as

 line balancing for maximum ut5ilization of labour and equipment. aits efficiency is

 based on cycle time for tasks performed at each workstation.

**Lecture Notes**

**10. Layout Planning (arrangement of the conversion facility)**

Up to now we have been emphasizing the importance of planning by the operations manager. In the last two lectures, we focused on two aspects of conversion process design - establishing capacity and facility location. We continue to focus on planning by considering the internal arrangement of the conversion facility i.e. the ***layout planning***.

Layout design interrelates with the capacity decisions and the processing technology, both of which dictate some spatial requirements on the facility. On the input side of operations, e.g. capacity and technology require that certain quantities of raw materials be on hand, stored in appropriate places, to allow subsequent operations to flow smoothly. The *sizes and locations* of these storage and work-in-process areas must be considered in layout.

The locations of various departments must also be decided. Equipment maintenance departments may have to be located near some especially breakdown-prone departments to ensure continuous, uninterrupted work flows. At the output side of conversion, finished goods storage areas and the conveyances for getting finished products into storage must both be considered. The size of the product and the volume of output will dictate storage area requirements; but so will be the shipping plans, which are part of the physical distribution system. Large volumes of output produced to order may be transported directly from the end of the conversion line and packed into nearby railroad cars for immediate shipment. Or outputs may go into a large warehouse area, to be loaded after a future customer order has been received. The design of the system will determine costs of storage and materials handling. Some modelling techniques are useful for layout planning and behavioural factors must be considered too. What then is layout planning?

Layout Concepts

Layout planning affects operating costs and effectiveness. Different types of layout designs are applied in different situations.

The operating functions in both manufacturing and service organisations can be divided into two basic types: intermittent and continuous, depending on the degree of product standardization and volume of output.

1. Intermittent operations

This intermittent manufacturing is conversion with production characteristics of low product volume, general purpose equipment, labour-intense operations, interrupted product flow, frequent schedule changes, large product mix and made-to-order products. Services with these same characteristics (automobile repair facilities, for example) are also classified as intermittent conversion operations.

2. Continuous operations

These operations are featured by high product volume, special purpose equipment, capital-intense operations, uninterrupted product flow, few schedule changes, small product mix and standardized products made to inventory. Services with the continuous manufacturing operations too have the same characteristics as continuous conversion operations. However, most service conversion processes are intermittent rather than continuous.

Basic Layout Designs

A basic layout design is the location or configuration of departments, work stations, and equipment that constitute the conversion process. It is the spatial arrangement of the physical resources that are used to create the product.

To gain a better understanding of the basic layout designs, three designs are examined:

1. Process-oriented design

 This design is used when work flows are not standardized for all units of output, a condition that is found in intermittent manufacturing. Unstandardized work flows occur either when a variety of different products is produced, or when one basic type of product with many possible variations is made. Distribution warehouses, hospitals and medical clinics, universities, office buildings and job shops facilities are often designed in this manner.

 In the process layout, the processing components (work centres or departments) are

 grouped together according to the type of function they perform. See diagram of a

 medical clinic given below:

 Neurology Obstetrics/gynaecology Laboratory tests

 Rest Patient

 rooms waiting X-ray

 area

 Reception

 room Plastic and

 reconstructive

 surgery

 Paediatrics

 Paediatrics

 Pharmacy

 Example patient flow

 Another characteristic of process layouts is the grouping of similar types of machines so

 that the product can travel to the machines required by the operation (see diagram

 below).

 Lathe #1

 Drill press #1 Lathe #2 Paint machine

 Lathe #3 Packaging machine #1

 Finish

 production

 Drill press #2 Lathe #4 Packaging machine #2

 Product #17358

 Start production

2. Product–oriented design

Product-oriented layouts are used when one standardized product is being produced, usually in large volume (a characteristic of continuous manufacturing). Each of the units of output requires the same sequence of operations from beginning to end. In product layout, work centres and equipment are therefore ideally arranged in a line to provide the specialised sequence of operations that will result in product build up. Each work centre may provide one highly specialised part of the total build-up sequence. Automatic car washes, cafeteria serving lines, ,ass medical exams for military recruits, automatic assembly and beverage bottling plants use product-oriented layouts.

 Example a product layout in manufacturing:

 Lathe Drill

 press #1

 Product #1234 Packaging Finish

 Start machine #2 production

 production

 Drill Paint

 press machine

 #2

3. Fixed-position design

 Fixed-position layouts are necessary when, because of size, shape or any other

 characteristic. It is not feasible to move the product. In fixed-position layout, the product

 remains in one location; tools, equipment and human skills are brought to it, as needed, to

 perform the appropriate stages of build-up. Layouts for building ships, locomotives and

 aircraft are often of this type, as are agricultural operations, in which ploughing, planting,

 fertizing, and harvesting are performed as needed in the fields.

4. Combination layouts

 Often pure layouts do not exist, an a combination layout must be used. This is most

 common for process and product combinations.

Does it really matter what type of basic design is selected? Yes. The appropriate layout depends upon many factors: anticipated volume, degree of product standardization, physical characteristics of the product, available alternative technologies and the availability of adequate long-term and short-term financial resources.

See the summaries of ways by which basic layouts differ from one another in the next page.

For some products, only one type of conversion process may be technologically feasible. In those cases, the process will dictate the type of layout design. But sometimes several methods of conversion may exist. Then the choice of layout design should be based on relative economic advantages and the availability of financial resources. Behavioural and modelling techniques are also important for evaluating design alternatives in both product and process layouts.

Characteristics of layout designs

|  |  |  |  |
| --- | --- | --- | --- |
| Aspect of the conversion process | Product-oriented | Process-oriented | Fixed-position |
| Product  characteristics | Layout geared to producing a standardized product, in large volume, at stable rates of output. | Layout for diversified products requiring common fundamental operations, in varying volume, at varying rates of output | Low volume, each unit often unique |
| Product flow  pattern | Straight line flow of product; same sequence of standard operations on each unit | Diversified flow pattern; each order (product) may require unique sequence of operations | Little or no product flow; equipment and human resources brought to site as needed. |
| Human skills requirement | Tolerance for performing routine, repetitive tasks at imposed pace; highly specialized work content | Primarily skilled craftsmen, can perform without close supervision and with moderate degree of adaptability | High degree of task flexibility often required; specific work assignments and location vary |
| Supporting staff | Large administrative and indirect support staff for scheduling materials and people, work analysis and maintenance | Must possess skills for scheduling, materials handling, and production and inventory control | High degree of scheduling and coordinating skills required |
| Material handling | Material flows predictable, systematized and often automated | Type and volume of handling required is variable; duplication of handling often occurs | Type and volume of handling required is variable, often low; may require heavy-duty general purpose handling equipment |
| Inventory requirement | High turnover of raw material and work-in-process inventories | Low turnover of raw material and work-in-process inventories; high raw materials inventories | Variable inventories due to lengthy production cycle can result in inventory tie-ups for long periods |
| Space utilization | Efficient utilization of space, high rate of product output per unit of space | Relatively low rate of output per unit of facility space; large work-in-progress requirements | For conversion within the facility, a low rate of space utilization per unit of output may occur |
| Capital requirement | High capital investment in equipment and processes that perform very specialized functions | Equipment and processes are general purpose and feature flexibility | General purpose equipment and processes that are mobile |
| Product cost components | Relatively high level fixed costs; low unit direct labour and materials costs | Relatively low fixed costs; high unit costs for direct labour, materials (inventory) and materials handling | High labour and materials costs; relatively low fixed costs |

Strategic Importance of Layout Decisions

The long run efficiency of operations depend on the layout of the conversion facility i.e. the layout planning.

The layout design of the production facilities enables the organisation to achieve competitive advantage in relation to factors such as capacity, processes, flexibility, cost, quality of work life, customer contact and image and reputation. This is because it helps the organisation to achieve its strategy such as differentiation, low cost or response.

The objective of layout strategy is to develop an effective and efficient layout that will meet the firm’s competitive requirements. Therefore, a layout design must enable the firm to achieve the following:

* Higher utilization of space, equipment and people
* Improved flow of information, materials or people
* Improved employee morale and safer working conditions
* Improved customer/client interaction
* Flexibility (whatever the layout is now, it will need to change)

The layout design must be viewed to be in a dynamic situation. It means that there must be flexibility in the layout of the facilities. Equipment can be shifted whenever necessary.

Cellular Layouts

Cellular production is a type of layout in which workstations are grouped into what is referred to as a cell. Groupings are determined by the operations needed to perform work for a set of similar items, or part families that require similar processing. The cells become miniature version of product layouts. The cells may have no conveyorized movement of parts between machines, or may have a flow line connected by a conveyor (automatic transfer). In the cellular layout, machines are arranged to handle all of the operation necessary for a group (family) of similar parts. Thus, all parts follow the same route although minor variations (e.g. skipping an operation) are possible. In contrast, the functional layout involves multiple paths for parts. Moreover, there is little effort or need to identify part families. The order in which the items move through the path is simple. The cellular layout design is effectively used in (for example):

(1) In single-minute exchange of die (SMED) – where a machine or process can be quickly converted to produce a different (but similar) product type. In this way a single cell can produce a variety of products without the time-consuming equipment changeover associated with large batch processes, enabling the organisation to quickly respond to changes in customer demand.

(2) Right-sized equipment – where smaller equipment and mobile equipment is used so that it can quickly be reconfigured into a different cellular layout in a different location.

Effective cellular manufacturing must have groups of identified items with similar processing characteristics. This strategy for product and process design is known as ***group technology*** and it involves identifying items with similarities in either *design characteristics or manufacturing characteristics*, and grouping them into *part families*.

Design characteristics: size, shape and function.

Manufacturing or processing characteristics: type and sequence of operation required.

Design and processing characteristics are correlated in most of the cases.

The conversion to group technology and cellular production requires a systematic analysis of parts to identify the part families. This is often a major undertaking; it is a time consuming job that involves the analysis of a considerable amount of data. Three primary methods for accomplishing this are visual inspection, examination of design and production data and production flow analysis. Vision inspection is the least accurate of the three but also the least costly and the simplest to perform. Examination of design and production data is more accurate but much more time-consuming; it is the most commonly used method of analysis.

Conversion to cellular production can be costly. The manager must weigh the benefits of a switch from a process layout to a cellular one against the cost of moving equipment as well as the cost and time needed for grouping parts. Flexible manufacturing systems (FMS) are more fully automated version of cellular manufacturing.

Flexible Manufacturing Systems

A ***flexible manufacturing system (FMS***) is a group of machines that include supervisory computer control, automatic material handling, and robots or other automated processing equipment. Such a system is capable to produce a variety of similar products and the number of machines can range from 3 to more than a dozen.

FMSs offer reduced labour costs and more consistent quality compared with traditional manufacturing methods, lower capital investment and higher flexibility than ‘hard’ automation, and relatively quick change over time.

Limitations:

* This type of system can handle a relatively narrow range of part variety and it is used for a family of similar parts, which all require similar machining.
* It requires longer planning and development times than more conventional processing equipment because of its increased complexity and cost.
* It represents a sizable chunk of technology.

Computer-integrated manufacturing (CIM) - a system that used an integrating computer system to link a broad range of manufacturing activities - such engineering design, flexible manufacturing systems, purchasing, order processing and production planning and control. Not all elements are absolutely necessary. Besides, more than one CIM system can be linked to the same computer thereby bring out the integration of information from other areas of an organisation with manufacturing.

The overall goal of using CIM is to link various parts of an organisation to achieve rapid response to customer orders and/or product changes, to allow rapid production, and to reduce indirect labour costs. Orders can be completed and shipped within 24 hours of entry into the system, indirect labour costs and inventory costs have been greatly reduced and quality is very high.

***Service Layouts***

Many service organisations use process layouts because of variability in customer processing requirements. These include hospitals, and other medical facilities, banks and other financial institutions, service centres, supermarkets, department stores and other retail establishments, offices and warehouses. Unlike manufacturing layouts, service layouts must be aesthetically pleasing as well as functional.

Some of the layouts:

* Warehouse and storage layouts - the design of storage facilities presents a different set of factors than the design of factory layouts. Frequently ordered items should be placed near the entrance to the facility and those ordered less frequently are placed toward the rear of the facility. On the other hand, items that are correlated are placed near to each other and this arrangement helps to reduce cost and time of picking those items. Other considerations are the number and widths of aisles, the height of storage racks, rail and/or truck loading and unloading and the need to periodically make a physical count of stored items.
* Retail layouts - the objective of retail layouts often pertain to cost minimization and product flow. However, with retail layouts such as department stores, supermarkets and specialty stores, designers must take into account the presence of customers and the opportunity to influence sales volume and customer attitudes through carefully designed layouts. Traffic patterns and traffic flow are important factor to consider. Large retail chains use standard layouts for all or most of their stores. This has several advantages:

- It saves time and money by using one layout instead of custom designing one for each

 store.

- It avoids confusing consumers who visit more than one store.

For smaller stores the layout designs are much simpler.

* Office layouts - Going transformations as the flow of paperwork is replaced with the increasing use of electronic communications. There is therefore less need to place office workers in a layout that optimizes the physical transfer of information or paperwork.

There is also the transformation is the creation of an image of openness and office walls are giving way to low-rise partitions.

Designing Product Layouts:

Line Balancing

The goal of a product layout is to arrange workers or machines in the sequence that operations need to be performed. The sequence is referred to as a production line or an assembly line. These lines can be fairly short to long lines that have a large number of operations. Automobile assembly lines are examples of long lines.

Advantages:

* The ability to divide required work into a series of elemental tasks that can be done quickly and routinely by low-skilled workers or specialized equipment.
* The durations of these elemental tasks can be determined.
* Tasks can be grouped into manageable bundles and assigned to workstations staffed by one or two operators.

Line balancing is the process of deciding how to assign tasks to workstations. The goal of line balancing is to obtain task groupings that represent approximately equal time requirements. This minimizes the idle time along the line and results in a high utilization of labour and equipment. Lines that are perfectly balanced will have a smooth flow of work as activities along the line are synchronised to achieve maximum utilization of labour and equipment.

Problems of line balancing:

* Difficult to attain a perfect balanced line because of the difficulty to form task bundles that have the same duration.
* Difficult to combine certain activities into the same bundle, either because of differences in equipment requirements or because the activities are not compatible.
* Not able to perfectly balance a line because a required technological sequence may be prohibited.

Line balancing involves assigning tasks to workstation. Usually, each workstation has one worker who handles all of the tasks at that station, although an option is to have several workers at a single workstation.

The primary determinant is the ‘**cycle time’**. It is the maximum time allowed at each workstation to perform assigned tasks before the work moves on. The cycle time also establishes the output rate of a line.

Task grouping and cycle time

The work to fabricate a certain product can be divided into 5 elemental tasks with the task times and precedence relationships as shown in the diagram below:

 0.1 min. 0.7 min 1.0 min 0.5 min 0.2 min

The task times govern the range of possible cycle times.

* The minimum cycle time is equal to the ***longest*** task time (1.0 minute).
* The maximum cycle time is equal to the sum of the task times (0.1 + 0.7 = 0.1.0 + 0.5 + 0.2 = 2.5 minutes).
* The minimum cycle time would apply if there were five workstations.
* The maximum cycle time would apply if all tasks were performed at a single workstation.

The minimum and maximum cycle times are important because they establish the potential range of output for the line, and it is possible to compare them by using the formula:

 Operating time per day

 Output rate =

 cycle time

If the line operates for 8 hours per day (480 minutes) and with a cycle time of 1.0 minute, the output would be:

 480/1 = 480 units per day.

With a cycle time of 2.5 minutes, the output would be:

 480/2,5 = 192 units per day

The output selected for the line must fall in the range of 192 units per day to 480 units per day.

On the other hand the cycle time can be determined by

 operating times per day

 Cycle time =

 desired output rate

If the cycle time does not fall between the maximum and minimum bounds, the desired output rate must be revised.

Suppose the desired output rate is 480 units, the necessary cycle time is

 480 minutes per day

 = 1.0 minute per unit

 480 units per day

The number of workstations that will be needed is a function of both the desired output rate and the ability to combine elemental tasks into workstations.

 ∑t

 Nmin  =

 Cycle time

 where

 Nmin = Theoretical minimum number of stations

 ∑t = Sum of task times

Suppose the desired rate of output is the maximum of 480 units per day. The minimum number of stations required to achieve this goal is

 2.5 minutes per unit

 Nmin = = 2.5 stations

1 minute per unit per station

Because 2.5 stations is not feasible, it is necessary to round up to three stations. Thus, the actual number of stations used will equal or exceed three, depending on how successfully the tasks can be grouped into work stations.

A very useful tool in line balancing is a precedence diagram as shown below.

 0.1 min 1.0 min

 a b

 c d e

 0.7 min 0.5 min 0.2 min

It portrays the tasks that are to be performed along with the sequential requirements. The diagram is read from left to right, so the initial task(s) are on the left and the final task is on the right. In terms of precedence requirements, task ‘a’ must be completed first before starting task ‘b’. However in order to begin task ‘d’, tasks ‘b’ and ‘c’ must be completed.

How a line is balanced. It involves assigning tasks to workstations. No technique is available for this, but to use heuristic (initiative) rules. Two of which are described here for purposes of illustration:

1. Assign tasks in order of most following tasks.

2. Assign tasks in order of greatest positional weight. Positional weight is the sum of each

 task’s time and the times of all following tasks.

The general procedure used in line balancing is as follows:

1. Determine the cycle time and the minimum number of workstations.
2. Make assignments to workstations in order, beginning with Station 1, Tasks are assigned to workstations moving from left to right through the precedence diagram.
3. Before each assignment, use the following criteria to determine which tasks are eligible to be assigned to a workstation:
4. All preceding tasks in the sequence have been assigned.
5. The task time does not exceed the time remaining at the workstation.

If no tasks are eligible, move on to the next workstation.

1. After each task assignment, determine the time remaining at the current workstation by subtracting the sum of times for tasks already assigned to it from the cycle time.
2. Break ties that occur using one of these rules:
3. Assign the task with the longest task time.
4. Assign the task with the greatest number of followers.

If there is still a tie, choose one task arbitrarily.

1. Continue until all tasks have been assigned to workstations.
2. Compute appropriate measures (e.g. percent idle time, efficiency) for the set of assignments.

(Read for more detail)

Other approaches

There are a number of other approaches companies use to achieve a smooth flow of production. One approach is to use parallel workstations. These are beneficial for bottleneck operations which would otherwise disrupt the flow of product as it moves down the line. The bottlenecks may be the result of difficult or very long tasks. Parallel workstations increase the work flow and provide flexibility.

Another approach to achieving a balanced line is to cross-train workers so that they are able lto perform more than one task. Then when bottlenecks occur, the workers with temporarily increased idle time can assist other workers who are temporarily overburdened, thereby maintaining an even flow of work along the line. This is sometimes referred ta as dynamic line balancing and it is used most often in lean production systems.

Still another approach is to design a line to handle more than one product on the same line This is referred to as a mixed model line. Naturally, the products have to be fairly similar, so that the tasks involved are pretty much the same for all products. This approach offers great flexibility in varying the amount of output of the products.

Designing Process Layouts

The main issue in designing process layouts concerns the relative positioning of the departments involved . Departments must be assigned to locations. The problem is to develop a reasonably good layout; some combinations will be more desirable than others. For example, some departments may benefit from adjacent locations whereas others should be separated. A lab with delicate equipment would not be located near a department that had equipment with strong vibrations. Conversely, two departments that share some of the same equipment would benefit from being close together.

Layouts can also be influenced by external factors such as the location of entrances, loading docks, elevators, windows and areas of reinforced flooring. Also important are noise levels, safety and the size and locations of restrooms.

In some instances (e.g. the layouts of supermarkets, gas stations and fast-food chains), a sufficient number of installations having similar characteristics justify the development of standardized layouts. E.g. the use of the same basic patterns in McDonald’s fast-food locations facilitates construction of new structures and employee training. Food preparation, order taking, and customer service flow the same pattern throughout the chain. Installation and service of equipment are also standardized. This same concept has been successfully employed in computer software products such as Microsoft Windows and the Macintosk Operating System. Different applications are designed with certain basic features in common, so that a user familiar with one application can readily use other applications without having to start from scratch with each new application.

The majority of layout problems involve single rather than multiple locations, and they present unique combinations of factors that do not lend themselves to a standardized approach. Consequently, these layouts require customized designs.

A major obstacle to finding the most efficient layout of departments is the large number of possible assignments. E.g. there are more than 87 billion different ways that 14 departments can be assigned to 14 locations if the locations form a single line. There is no one best layout arrangement under all circumstances. Often planners rely on heuristic rules to guide trial-and –error efforts for a satisfactory solution to each problem.

An effective process layout must be able to satisfy a variety of processing requirements:

* the smooth flow of materials
* movement of people from work centre to work centre should be of minimum distance, cost or time.

Information requirements:

The design of process layouts requires the following information:

1. A list of departments or work centres to be arranged, their approximate dimensions, and the dimensions of the building or buildings that will house the departments.
2. A projection of future work flows between the various work centres.
3. The distance between locations and the cost per unit of distance to move loads between locations.
4. The amount of money to be invested in the layout.
5. A list of any special considerations (e.g. operations that must be close to each other or operations that must be separated).
6. The location of key utilities, access and exit points, loading docks and so on, in existing buildings.

The most common goals in designing process layouts are minimization of transportation costs or distances travelled. Another important consideration is the relative closeness of the departments.

The size and complexity of process layout problems have led to the development of a number of computerised packages that enable large problems and many layout alternatives to be handled.