Facility Layout

10

Unit Introduction

Layout means the arrangement or configuration of the departments within the facility and also the arrangement of economic activity centers within each department. An economic activity center can be anything that is essential for that department and at the same time consumes space, such as, a person, an equipment, an aisle, a tool crib, a computer table, even a staircase. Facility layout decision is important because it has long term implications. It is very costly to redesign a building or to relocate to a new site, which means that it is necessary to ensure that the original design or location selection is well thought of before implementing the plan. In general, layout decisions are important because: it requires substantial investments of money and effort, it involves long-term commitments, which makes mistakes difficult to overcome, and it has a significant impact on the cost and efficiency of operations. Therefore this unit will discuss about different types of facility layout and their advantages and disadvantages including uses.

Lesson One: Facility Layout

Lesson objectives
After completing this lesson you will be able to:

- Describe the strategic issues of facility design
- Explain the objectives of a good layout
- Discuss the different types of layout formats
- Identify the distinguishing features of the basic layout types

The frequency of layout decisions is dependent on the type of facility under consideration. In automated manufacturing where machines are large and special-purpose frequent relocation is very costly and at times prohibitive. In labor intensive manufacturing the production facilities are less fixed, therefore, initial layout planning is less critical. On the other hand, in the labor intensive services, where the emphasis is on flexibility and change, the trend is to undergo frequent re-designing of facilities.

Strategic Issues of facility design
The need for facility layout arises because, the organization has decided to move to a new location, or the present facility layout is no more effective. When an organization moves to a new location the question arises, within each department, where to locate the different economic activity centers. The objective is to arrange these activity centers in a way that would ensure a smooth workflow or a particular traffic pattern that would result in efficient and effective operations. In addition, some of the most common causes for redesigning an existing facility layout arise out of the following:

- Sudden rise in operating cost with marked fall in output
- Increase of accidents in the work centers
- Introduction of new production technology
- Changes in product design or services
- Changes in the product mix or services
- Increase in worker turnover, absenteeism, anxiety or strain
- Skilled workers doing unskilled works, etc.

The above points do give us an indication that layout has many strategic implications for the organization. Altering an existing layout or selecting a new layout can affect an organization's ability to meet competition in the market.

Objective of a Good Layout
Facility layout is important for many reasons. The major objective is to design a facility so that operations can be carried out as cost effectively as possible. Several factors contribute to operations costs, some direct and some indirect. Workers safety, moral, etc. indirectly contribute to cost. Similarly, material movement, space utilization contributes directly to cost of operations. For this reason, some or all of the following objectives are attempted through facility layout:

The major objective of a good layout is to design a facility so that operations can be carried out as cost effectively as possible.

- Facilitate flow or movement of materials and information
- Identify and reduce bottlenecks

- Reduce machine interference
- Improve working conditions and employee satisfaction
- Increase efficient utilization of equipment and labor
- Utilize available space effectively and efficiently
- Provide ease of supervision and control
- Ease of future expansion or contraction
- Compatibility with long range plans
- Reduce the level of capital investment, etc.

To come up with an effective solution, operations managers must decide, early in the process of layout designing, which of the many objectives to incorporate in the layout. In most cases multiple objectives are used. With multiple objectives to accomplish, it is not an easy job. In addition, type of operations to be performed and the volume also tends to influence the layout type. For example, production of heavy products places special emphasis on material handling capabilities, whereas, in warehouse the emphasis is on easy stock picking, flexibility and amount of space.

Activity: In order to design a product plant of any (chose yourself) – what factors you will consider and why? Discuss.

Types of Layout

The formats by which workstations are arranged within a facility are defined by the general pattern of work-flow. Although there are many work-flow patterns, we can classify the different layout format into four (4) basic types as:

- Process layout,
- Product layout and
- Fixed-position layout, and
- Hybrid layout.

In this lesson we would be looking into the characteristics, advantages, and disadvantages of the different types of layout.

Process Layout

Product layout or job-shop layout is a format in which similar equipment or functions are grouped together.

When demand for a particular product or service is not very high or is unpredictable or when an organization is expected to provide different types of product, of similar nature, it does not make economic sense to dedicate different sets of equipment and personnel to each product or service. In this type of situation, to ensure maximum utilization of resources and facilities, the workstations are grouped together according to their specialization. A product layout, also known as job-shop layout, is a format in which similar equipment or functions are grouped together. Many organizations arrange their facilities in this manner; for example, in a machine-shop all drill machines are located in one area, all lathe machines in another area, and all milling machines in yet another area. A product being worked on travel, in lots, from one location to another, according to their required sequence of operations. Different product would require different sequence of movement through the facility. For example, one product may visit the lathe area twice, whereas, another may not go there at all. The Figure 10.1.1 below shows a typical process layout format.

Process layout is also common in office and non-manufacturing organizations. Most offices are arranged according to the nature of functions carried out by the employees, for example, Accounts Department, Marketing Department, Purchase Department, etc. This type of arrangements are also noted in hospitals, library, banks, universities, and restaurants. For instance, in hospital the facilities are arranged according to the type of treatment provided, like units that handle maternity, surgery, pediatrics, and emergency. In universities we come across School of Business, School of Medicine, School of Science, etc., each providing specialized teaching.

Some of the *advantages* of process layout are:

- *Flexibility in use of equipment and employees:* The system can handle variety of processing requirements, a much needed quality, when a company provides a variety of product or service.
- *Flexibility in pace of operations:* The system is less vulnerable to changes in the market demand pattern, product mix or internal change in marketing strategy.

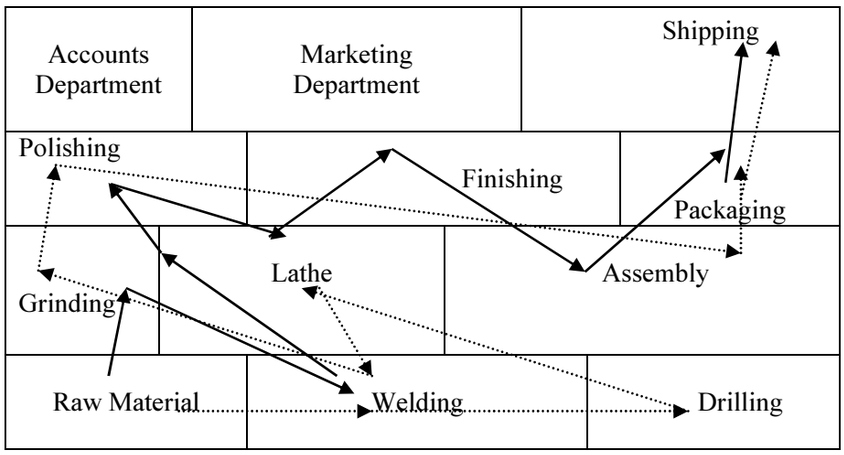

Figure 10.1.1: Typical process layout format

- *Investment:* Smaller investment in equipment because the layout avoids duplication of equipment. In addition, the resources are relatively general purpose, which are often less costly and easier to maintain. On top of it, similarity of machine reduces the need to invest in different types of spare parts.
- *Equipment failure:* The system is less vulnerable to equipment failure or absenteeism of employees, because idle equipment are usually available to replace machines which are temporarily out of order.
- *High utilization of resources:* The design of the facility allows pooling of resources. When the demand for a particular product is low, it does not justify setting aside a group of equipment and employees for that product alone. Same set of equipment can be used to service different types of product ensuring that the resource does not sit idle.

- *Less interdependence of operations:* Since the products are processed in lots, there is considerably less interdependence between successive operations.
- *Specialized supervision:* Supervisors, in general, are responsible for a single specialized area like lathe or grinding section resulting in them becoming highly knowledgeable about the function under their direction.
- *Workers' morale:* Diversity of task ensures high moral of workers. Most workers get job satisfaction if there is variation in their work assignment.
- *Incentive plan:* In process layout, where the final product can be easily attributed to a specific employee, it is easy to develop and implement individual incentive system.

Some of the *disadvantages* of process layout are:

- *Material handling:* Backtracking and long movement results in inefficient material handling. Automated and efficient handling equipment are not suited for this type of layouts, necessitating the use of variable path devices as wheel borrow.
- *Routing and scheduling:* Since same set of machines are used to process different types of product, it is very difficult to plan and schedule production. The time lag between order receipt and delivery tends to be long.
- *Lower productivity:* The processing rate tends to be slow. Because each job is different, it requires different setups, and thus production time is lost in changing from one product to another. At times, workers must wait long period between tasks.
- *Space and inventory:* Because of jumbled and variable flows, more space and capitals are tied up in inventory. Valuable inventory tends to build up around each job, requiring expensive storage space and results in delay in delivery.
- *Span of supervision:* Job complexities often reduces the span of supervision requiring more supervisors to give attention to fewer workers resulting in higher supervisory cost.
- *Wages:* Because of job complexity the workers need to have extensive training and broader skills that tends to push wages higher.
- *Other management functional area:* Other management functional areas like accounting, inventory control, production control, are much more involved than in any other type of layout.

The primary objective of a process layout is to locate each workstation in such a way that it improves the functional relationships of the workstations that makeup the facility.

Activity: How can you overcome some of the disadvantages of the process layout? Justify with reasonable example.

Product Layout

When the resources and activities are arranged according to the processing needs of a single product, rather than shared among different types of product, we call it a product layout. In a process layout, the products move in a zig-zag manner from center to center. But in a product layout the flow of the product is always in a straight line or L, S or U line shaped (see figure) and the product never backtrack towards the beginning of the line. A product layout is often called an assembly line, production line, or flow-line layout.

Product layout is often called an assembly line or production line or flow-line layout.

A product layout design is possible only if the design of the product is highly standardized, there is a high demand for the product and the product processing operations is standardized and repetitive in nature. In this type of layout the jobs are divided into series of standard tasks, permitting specialization of both labor and equipment. Straight line arrangement of resource centers permits use of automatic conveyor belts to handle materials. Product layouts often rely heavily on specialized, capital-intensive resources. But the additional cost of these specialized equipment are offset by large production volume that this type of system generally handles.

In product layout because operations must occur in predetermined order it is very easy to decide where to locate different resource centers. For example, in a cafeteria a student must first pick up a tray, then go for a plate of rice, next a bowl of meat/fish then a bowl of dal and a glass of water. Finally he has to pass by the cashier to pay for what he wants to eat. Food arranged in this sequence would ensure easy flow of students through the system. The challenge is to group together activities into workstations that reduces the need for the lowest level of resources. At a later lesson we will describe the technique of line balancing, a technique that is used to reduce the total number of workstation required for the system.

Some of the *advantages* of product layout are:

- *High rate of output:* Output is generally high in product layout because the resources are dedicated to only a specific product, workers do repetitive work and the flow of product can be regulated.
- *Lower inventories:* There are less need to decouple one operation from the next, and items move directly from one operation to the next without interruption, resulting in less need to invest in work-in-process inventories.
- *High degree of utilization:* In product layouts there is high degree of utilization of both labor and machineries. Because of simplified flow of work, less time is lost in unproductive activities like change-overs, re-tuning of machineries, wait for materials, etc. This in turn reduces per unit cost of production.
- *Division of labor:* The nature of arrangement of resources permit jobs to be divided into series of standard tasks, that can be carried out by unskilled labors who can be trained quickly. Thus need for extensive training is reduced, resulting in low costs for training. It also results in high span of supervision.

- *Reduced material handling costs:* Per unit material handling is low because of the ability to use mechanical material handling equipment like conveyor belts. Flow of work is in a straight line which is suitable for use of conveyor belts or other automatic mechanical handlers.
- *Simplified production planning and control:* At the design stage production planning and control are built into the system. Once the system is fine-tuned it does not require much attention from the planners. For regular day-to-day works, predetermined plans and controls can be used again and again.
- *Simplified flow of product through the system:* The machinery are such arranged that the product does not have to backtrack through the system.

Activity: What more advantages the product layout may have? Why do you think your chosen advantages should be included with the above? Justify.

Some of the major *disadvantages* of product layout are:

- *Lack of flexibility:* The system is not at all flexible. Change in product design or volume may require extensive and expensive changes in the system.

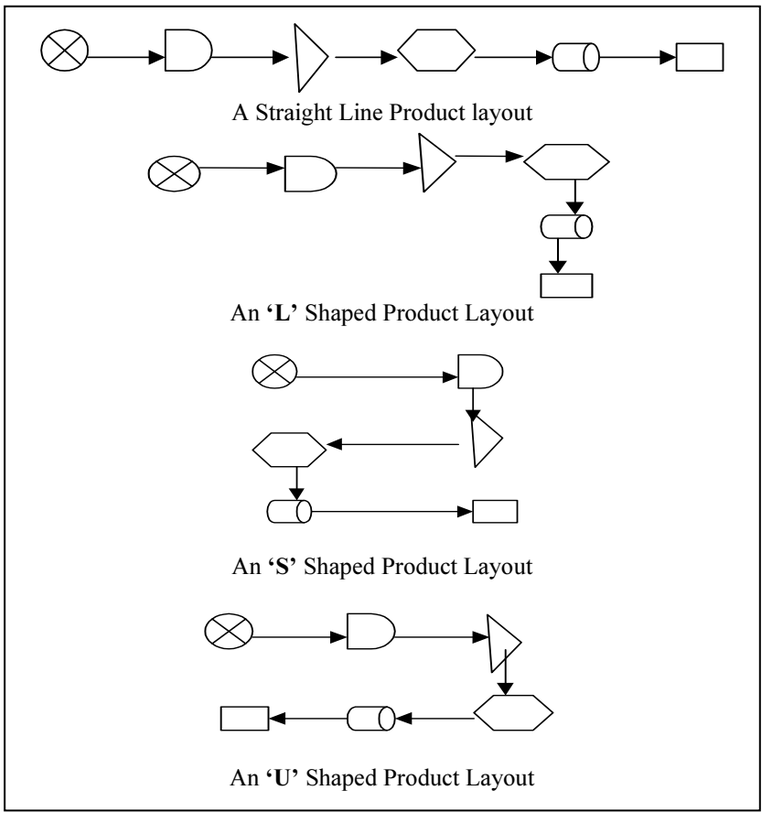

Figure 10.1.2: Typical process layout formats

- *Large investment:* Duplication of equipment is not at all uncommon in product layout. Multiple of the same type of equipment may be required

by the system to ensure no backtracking of the flow of the product through the system. In addition, this type of layout require special-purpose automated equipment. All these results in high investment in equipment.

- *Division of labor:* Intensive division of labor results in workers becoming bored by the endless repetition of dull and simple tasks. Scope for advancements are few that leads to moral problem. Incentive plans are impractical because the rate of output of one worker is dependent on the speed of the workers preceding him.
- *Dependence of the whole on each part:* The system is highly susceptible to breakdowns or absence of workers. Each machine and labor in the system is dependent on others in the system. If one machine breakdown or if one worker remains absent the whole system collapses. For this reason, preventive maintenance is required on a regular basis to avoid unnecessary shutdowns. However, no amount of preventive measures can completely eliminate failure of machinery. The procedure of preventive maintenance can become very expensive because of the need to inventory large quantity of spares for the specialized equipment.

In the product layout if one worker remains absent or one machine breakdown then the whole system will collapses.

Fixed-Position Layout

The third type of layout is known as Fixed-Position layout. As the name implies the product stays stationary and, as required, it is the machines, workers and materials that keep on changing position. There are many products that are very heavy or large and as such is difficult to move, or can be moved at a high cost, such as aircrafts, ships, locomotives or tanks. On the other hand, there are products that are fragile and susceptible to breakage if moved frequently, like man-made earth satellite. There are also products that has to be produced where it is to be used and has to be anchored to the earth, like bridges, dams, and buildings. For all these type of products fixed position layout is most appropriate.

Products those are very heavy and difficult to move for them fixed position layout is most appropriate.

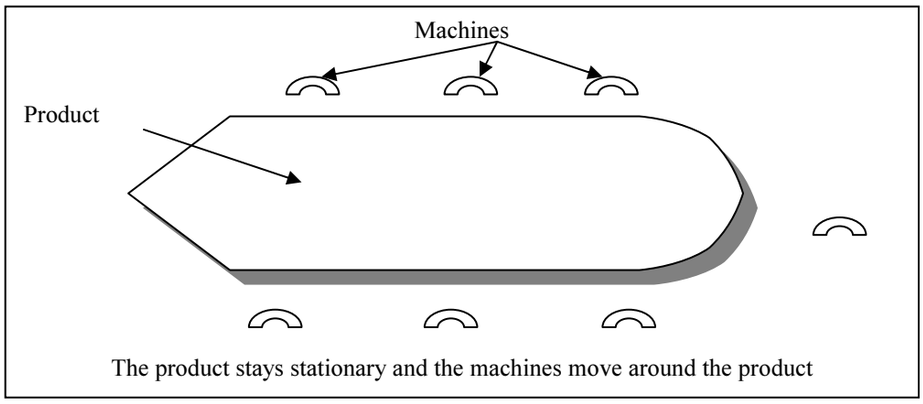

Figure 10.1.3: Typical fixed position Layout

A fixed position layout minimizes the number of time that a product has to be moved. The size and weight of the product necessitate this type of layout. The demand for the product is relatively low. In developing a fixed-position layout emphasis is always on the sequence of activities, schedule of the activities, and availability of space. In this type of layout tasks are arranged according to their process sequence requirement and material and machines are arranged and scheduled according to their technological priority. If scheduling of activities are

not done carefully machine and material along with labor would arrive ahead of their requirement and clog the available space. Lack of space can be a big headache for the planners. Diverse and specialized workers are generally required, resulting in narrow span of supervision, but the equipment used are of general purpose in nature.

> **Activity:** What are the basic differences among fixed position layout, product and process layout? Discuss.

Fixed position layout has the following *advantages*:

- *Cost and damage:* During the production stage the product is rarely moved, as such material handling cost is minimized and the chance of damage is reduced. Though the cost of material handling is reduced the cost of moving machinery and labor increases.
- *Continuity of work:* Since the product stays stationary and does not have to be moved from one production center to another, there is continuity of the assigned tasks. In process type of layout delays occur because of built up of work-in-process inventories at different departments or workstations. But in fixed position layout since there are no separate workstations, this type of delays are avoided.

Some of the *dis-advantages* of fixed position layout are:

- *Worker skill:* Same set of workers is expected to carryout different type of tasks. Recruitment of skilled general purpose workers are essential. The necessary combination of such skill can be obtained only at a high cost from the market or the in-house workers have to be given extensive training to develop the desired skills.
- *Supervision:* Span of supervision is narrow in fixed position layout. Same set of workers have to be employed at different stages of production requiring close supervision and attention.
- *Movement of machinery and material:* Materials, machinery and workers have to be moved frequently to and from the work area. This add to the total cost of production.
- *Utilization:* In this type of layout the utilization of production resources are low. Many of the resources are transported to site and after a sequence of use have to be kept on site, because they would be required at a later stage, instead of moved to another production site to make use of it during the idle period in the present site.
- *Administration:* Planning of the production, scheduling of tasks and control of activities are very important in this type of layout. All tasks are dependent on their preceding activities and space is generally in short supply, as such strict monitoring is essential to avoid clogging of space. Frequent rescheduling is the norm.

Hybrid Layout

Combination of *process and product* types of layout is known as hybrid layout. It is also commonly called combination layout, mixed layout, cellular layout, grouped technology, or flexible layout. The major emphasis of a hybrid layout is

to take advantages of the good features of process and product layout and at the same time avoid their shortcomings. Hybrid layout, where part of the operations are based on process layout and part on product layout, represent efforts to move toward this direction.

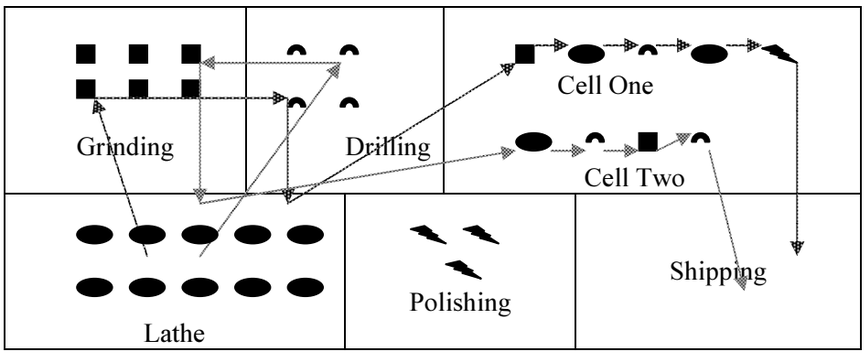

Figure 10.1.4: Hybrid layout

Many of the manufacturing organizations are moving away from pure process layout in their effort to take advantage of low per unit production cost that can be derived from product layout. But low volume of demand does not permit them to invest heavily on specialized equipment.

Some of the major *advantages* of hybrid layout are:

- *Facility utilization:* In hybrid layout facility utilization is generally high contributing to low per unit production cost. Grouping activities into cells reduces the number of time a machine has to be tooled or re-tooled. Inventory build-up is low in front of workstations and the need to wait for processing is reduced.
- *Worker morale:* Repetitive and simple tasks are combined with skilled activities giving the workers a sense of accomplishment. In many hybrid arrangements teamwork is essential. Morale is generally high in this type of arrangement.
- *Material handling and in-process inventory:* Hybrid layout groups act together reducing the total number of workstations and the need to move products from workstation to workstation. Material handling cost is low and the in-process inventory is also low.

Some of the major *dis-advantages* of hybrid layout are:

- *Planning and grouping products into common cells:* It is difficult to identify products that require same sequence of processing activities. At least at different stages of the production process some of the product may have a set of activities with similar or near similar sequences. It is not only difficult to identify the products but also their sequences, but it is also difficult to plan for those products and schedule their activities.
- *Equipment:* Hybrid layout requires automatic processing equipment. In most cases the worker is only responsible for loading and unloading the product and when required tooling and re-tooling the machine. These type of machine are expensive to buy and costly to maintain.

It is difficult to identify the product and its sequences and plan the activities.

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Discussion questions

1. What do you mean by layout?
2. What questions should a planner answer before selecting a layout format?
3. Describe the strategic issues involved in layout planning.
4. Explain the objectives of a layout design.
5. Can you explain why so much importance is given to plant layout?
6. What are the different types of layout you are familiar with? Describe them.
7. Describe the basic features of a hybrid layout.
8. Under what circumstance would you recommend the use of a process layout?
9. Describe the basic features of different layout.
10. What are the advantages and limitations of process and product layout?
11. How does a process layout differ from a product layout?
12. Explain the type of layout you would recommend for the following:
    (a) Airport, (b) Hospital, (c) Community Center, (d) School,
    (e) University, (f) Garment Factory, (g) Office, (h) Ferry Terminal.

Lesson Two: Designing Process Layout

Lesson objectives
After completing this lesson you will be able to:

- Describe the steps of designing process layout
- Explain the special features of warehouse, retail and office layout

At any given time hundreds and thousands of jobs pass through the work centers of a process focused organization. In most cases the jobs are non-standard, arrive at the work center in small lots, pass through the production facility following diverse routes and are difficult to schedule through the facility. But still majority of the organizations, whether manufacturing or service, have to rely on process focused layouts. In a process layout all the activities are classified and grouped together according to their functions. For example, in manufacturing, all milling machines in one section and all drill machines in another. In service, all the accountants in one room and all the salesmen in another. This grouping of activities simplify the procedure of designing a process layout, but still the problem of deciding on the relative position of the departments is too important to ignore. The main issue in design of a process layout concerns the relative position of the departments involved.

The main issue in design of a process layout concerns the relative position of the departments involved.

A major obstacle in finding the most efficient layout of departments is the large number of alternatives available to the planner. For example, if a plant has only six departments and if all of them have to be arranged in a straight line, one department after another, the planner has 720 different ways to arrange the facility, that is n! way of arranging the facilities. In addition to relative location of departments, space requirement of departments, shape of the room, need for reinforced floor, need to be in front or back of the building are other important factors affecting the location of departments. Furthermore, external factors like location of entrance, stairs, loading docks, windows, doors are other important factors. Also important are noise level, safety features, light and location of restroom. If all these factors are considered, the planner ends up with a limitless number of options. Identifying and arranging a process layout takes a long time unless some sort of heuristic rule is used.

Steps of Process Layout
Process layout planning procedure has not yet been standardized. Different planners propose different approaches to develop process layout. None of the approaches can guarantee optimum layout, but all seek to minimize movement cost. One such approach consist of the following steps:

1. *Determine site requirement:* If an existing facility has to be re-arranged, question arises whether the present site has sufficient space for expansion, if expansion is required. Expansion can be both horizontal and vertical. If the present location is not suitable for expansion then a new location has to be identified. Location selection depends on availability of the right type of land at the right price, availability of skilled workers or willingness of the present workers to move to new site, access to road and utilities, nearness to market or suppliers, community attitude, etc.
2. *Determine the space requirement of each department:* Forecasting techniques are used to determine the demand pattern, at least five years into the future, of the products and parts to be produced in the facility.

Next, production hour per product per department per month is estimated. The production hours per month indicates the number of workers and machines that would be required in the department. Machine shape and size and workers maneuverability and safety will determine the total space required for the department. With this are included space required for aisle, space for storage of in-process inventory and movement of material handling equipment.

3. *Determine the special structural requirements of each department:* Different department may need different type of building structure. Some department may use automatic storage and retrieval system (AS/RS), and would require a square or rectangular configuration. A department that uses overhead cranes may need sufficient space at the top. Department that use heavy and vibrating machines may need reinforced floor and has to be located on the ground floor. Departments handling flammable and explosive materials have to be situated away from all other activities.

Goal of determining the inter-departmental flow pattern is to find flow patterns that minimize both the time and cost of movement.

4. *Determine the inter-departmental flow pattern:* At first glance, the inter-departmental flow may appear to be jumbled up, but careful observation can easily discern dominant flow patterns. At this stage attempt is made to find those patterns. The goal is to find flow patterns that minimize both time of movement and cost of movement. In most organizations, the frequency and intensity of flow can be estimated on a daily basis. Activity-arrangement diagram is used to find the flow pattern between departments.
5. *Determine the total expected trips between departments:* It may not be possible to reduce the number of trips between departments, but the distance traveled can be minimized by placing departments close to each other. Using the flow pattern (Step 4) and forecasted production activities (Step 2), number of trips between different departments are estimated. In determining the number of trips it should be remembered that there may or may not be flow in both directions. But still the total expected trips between each department is simply the sum of travel in both direction. Trip Matrix method is one of the commonly used tool for this purpose.
6. *Determine the closeness priorities of departments:* Number of trips between departments can be an important priority factor for closeness or nearness. Departments with large number of trips, between them, should naturally be near to each other. Other factors may also influence nearness priority. For example, departments that shares common resources need to be close to each other. These factors are used to develop a priority list of departments. Departments with the highest priority are grouped together. Muther Grid or Relationship Charts (REL) are used at this stage.

The initial block plan may not produce the best layout and may not conform to the space and shape requirements of the departments.

7. *Develop an initial block plan:* Using the information generated in Step 5 and Step 6 a block plan is developed. A block plan specifies the relative location of different departments. The most elementary way to do so is by trial-and-error method. Success depends on the designer's ability to spot the patterns in the data. The initial block plan may not produce the best layout and may not conform to the space and shape requirements of the departments. But the objective is to develop a plan that is satisfactory and also accommodate the highest-level nearness priority first. Alternate designs are created for comparison. They are compared to determine their contribution to handling cost reduction. Load-Distance method along with cost is commonly used for this type of analysis.

8. *Modify space and shape requirements of departments:* The last step was used only to find the best location of each department without considering their space and shape requirements or any other special requirements. In this step attempt is made to conform to space, shape and special requirements of each department, without sacrificing the closeness priority requirement. Here again some type of heuristic and creative approach has to be adopted. Because of many reasons, some of the departments may end up with more space than they require, whereas, other departments may have to sacrifice some of their special requirements like nearness to the entrance, etc.
9. *Design a detail layout plan:* Once the relative and absolute position of each department has been identified and space allocated to them, the next step is to design detail plan for each individual department. Each department contain men, machine, furniture, and storage space, and these elements also has flow patterns among them. The dominant flow patterns among them have to be identified. Based on the flow patterns and trips required, between the work centers, the different elements of the departments are arranged. Scale models of the space and equipment may be used to evaluate the alternative arrangements. Sometimes templates are used during deliberations and drawings are made after the layout is decided upon. Diagrams and drawings are useful in giving a visual understanding of the situation so that potential problems are not overlooked.

Activity: Among the above steps of process layout – which do you think one most important for the organization? Why? Discuss.

Layout Design of Some Special Service Outlets

Most service organizations that we come across are process focused. Unlike manufacturing organizations, they interact directly with the customers. For this reason, great care is taken in layout of the service outlets to ensure that the customers have a favorable impression about the organization. The design steps described in the previous section are equally applicable in design of a service outlet. But still, some of the service outlets have special characteristics that need to be taken into consideration while their layout is designed.

A. **Warehouse Layout:** Time utility is the only objective of a warehouse. They store goods in anticipation of future demand. They do not come into direct contact with the end consumers. The only consideration in design of a warehouse is to find the best storage location of the goods, such that, it would be both easy to store and retrieve with minimum effort and cost. In a warehouse, goods have to be moved from the receiving bay to the storage location and from the storage location to the delivery bay. Movement of goods between storage location to storage location is not common. Frequency of order of a particular product is one of the prime consideration in warehouse layout design. Product with the highest number of orders per period, should naturally be stored near the loading dock for easy storage and retrieval.

Frequency of order is a major consideration in the warehouse layout design.

On the same principle, products with low frequency of order should be located away from the entrance. This would ensure a total of minimum distance moved to store and retrieve goods. Similarly, if order of one product

is dependent on that of another, then those products should be placed close together to reduce picking time and cost. For example, bakery raw materials like flour, sugar, cream, milk, etc are always ordered together, so storing them together close to each other makes sense. Storage racks height, product handling equipment, length and width of aisles, location of loading and unloading docks, seasonal variation of demand, etc. are other important factors considered in design of a warehouse. Methods used in warehouse layout are simple. If all product types require same storage space then placing the one requiring the most trips nearest to loading dock, and progressively the products requiring lower trips further away from the entrance. If products need different storage space then the product with the largest ratio of trip frequency to space are placed near the entrance than products with lower ratio.

B. **Retail Outlet Layout:** Retail outlets like banks, restaurants, boutique shops, fast food shops, departmental stores, super markets, have the objective to maximize net profit per square feet of store space. The retail outlet layout designer also has to take account of the presence of the customer in the facility. Design of the layout can directly influence attitude and buying behavior of customers. It can also control and direct the movement of customers through the facility. *Servicescape* is a term frequently used with reference to retail layout design. It refers to the physical surrounding in which service is provided and it's influence on the customers and the workers. Servicescape includes ambient conditions and spatial layout and functionality.

Design of the retail layout can directly influence attitude and buying behavior of customers.

Ambient conditions refers to the overall physical condition of the facility like noise level, lighting, background music, temperature, design of the furniture and fixtures, colour of the walls, smell, etc. These factors influence the perception of the customers about the quality of service provided by the outlet. They also influence the time that a customer spends in the facility which, in turn, contributes to the sales of merchandise.

Spatial layout and *functionality* directs the customers through the facility and at the same time ensures the visibility of the products. The goal is to create a layout with aisles passing through racks of products, such that, once the customer is in the outlet he/she has to pass by all the products offered by the outlet. Often called the "prison" because once you are in the store you are stuck until you come out the other end. The main aisle, the secondary aisle, and the tertiary aisles are all set at an angle to each other, that enhances visibility of merchandises.

Activity: What basic differences you can identify between warehouse layout and retail outlet layout? Discuss.

C. **Office Layout:** In recent days the need for planned office layout is drawing attention of the managers. More than 30 percent of our worker force are employed in office, and their productivity and quality of work depends on the physical environment in which they work. With increase use of computers the need for physical transfer of information is greatly reduced, resulting in opportunity of separating office workers from each other without affecting

their performance. At the same-time, companies are removing fixed partitions in their offices to foster greater teamwork.

Proximity and *privacy* are two important ingredients of an office layout. Easy access to co-workers enhances communication and mutual trust and respect. Proximity can be achieved by opening up the work place by replacing fixed walls with low-rise partitions. Need for privacy is also important in an office. Outside disruptions and crowding can hurt performance of workers. Privacy can be achieved by raising walls and doors. Both privacy and proximity are contradictory requirements of an office layout. Too much proximity reduces privacy and too much privacy reduces proximity. It is a dilemma to provide maximum of both, and management has to arrive at a compromise between the two. There are *four* different approaches to office,

Proximity and privacy are two important ingredients of an office layout.

i. Traditional office layout
ii. Office landscaping
iii. Activity centers, and
iv. Electronic cottages.

Traditional office layout provides maximum privacy and almost no proximity. Bureaucratic organizations follow traditional office layout. The layout is characterized by a long corridor with series of closed door on both sides, behind each door is a room and in each room there is a worker. In office landscaping layout each worker is provided with a low partition cubical. When he sits down he has complete privacy, but when he stands up he has the desired proximity. In other variant of landscaping, instead of low-rise partitions, plants, screens and portable partitions are used to separate co-workers to create the desired privacy.

Activity center layout is a new concept. It provides both privacy and proximity. Within the office, each worker has his own separate room as his home base, where he can work in privacy. But his home base is not provided with all the necessary utensils that he would require to complete his job. Important equipment like photocopy machine, telephone, computer, library, coffee machines, etc. are all provided at different work centers. During the course of his work he has to move from one work center to another, coming into contact with his co-workers.

Activity center layout provides both privacy and proximity.

Internet, e-mail and tele-conferencing are making present day office obsolete. Office is where you work. It may be at your home, on the way to office in your car, or any other place, as long as you are in touch with your office and are producing the desired output. Electronic cottage gives you the flexibility of when to work and where to work, for example, the function of a typist is to enter data into a computer. If he can do so while at home, the boss should have no reason to complain. This concept is very popular in developed countries where female workers with children prefer the flexibility of work schedule offered by this system. Major drawback of this system is the lack of proximity. Many of the workers never come across each other, and are not even aware of their existence.

Activity: Discuss the strategic importance of office layout design.

Quantitative Techniques used in Process Layout

A large number of factors are generally used to develop a process layout plan. But most of the techniques proposed to aid process layout plan relay on only one

A good process layout attempts to reduce the distance moved in the facility.

or two factors to determine the priorities in selection of an acceptable layout plan. The most frequently used factor is the flow pattern between departments. The two techniques shown in this section are variant of flow measurements. A good process layout attempts to reduce the distance moved in the facility. Movement of material between departments cannot be eliminated, but can be reduced. The more reduction in the movement of materials between departments the more the saving of handling cost. Handling cost is a necessary evil that has to be incurred but it does not add to value of the product. The objective of analysis of flow pattern is to identify interdepartmental traffic and minimize the traffic by placing departments with large traffic adjacent to each other.

If the product mix and volume of products are known, then it is easy to develop a matrix representing the trips.

a) **Trip-matrix with cost:** The designer, at first, estimates the expected average number of trips to be made, in a given period, between pair of departments. He can use the previous routing sheets or ordering sheets to find the desired number of trips, or he can carry out statistical sampling of the opinions of supervisors and material handlers, or physical observation of the operating system. If the product mix and volume of products are known, then the designer can easily develop a matrix representing the trips that are made between pairs of departments. If the cost of movement between pair of departments are same then only the sum of trips between the departments are relevant.

   Next, the designer collects information on cost of movement of materials between departments. Cost of material handling depends on the nature of product, volume, distance moved, and type of handling equipment used. The total cost of movement between two departments gives us the desired information to develop nearness priorities. Using heuristic method desired layout for the organization is developed.

Load-distance method uses actual distance moved between departments.

b) **Load distance method:** A variation of trip-matrix is load-distance method. Load-distance method in place of trips between department uses actual distance moved. It compares costs between different alternatives and selects the one that gives the lowest cost. The major problem with this method is that it has first to identify all the different layout plans available and then find their total cost for comparison. As stated in the beginning of this lesson, there are **n!** number of ways to arrange a process layout. For example, 10 departments can be arranged in 36,28,800 different ways. Unless all the alternatives are identified and compared, it would not be possible to identify the best and optimum layout design. Of course, half of the alternatives would be mirror images of the other half, but still identifying 18,14,400 (36,28,800/2) and comparing them would be a daunting task.

Subjective criterion can be incorporated to indicate the relative importance of each combination of pairs of departments.

c) **Muther grid or relationship chart (REL chart):** Although the preceding techniques are widely used in design of process layout, they suffer from the limitation of using only transportation cost to determine the priorities for location. In reality, location decision is dependent on multiple of criteria, many of them qualitative in nature. Muther developed an approach in which subjective criterion can be incorporated to indicate the relative importance of each combination of pairs of departments. Muther called his approach Systematic Layout Planning (SLP), it is also known as Muther Grid or REL Chart. The Chart (Grid) uses symbols to represent the desire or need for closeness of departments. Closeness importance are developed by analyzing the flow patterns between different pairs of departments.

Opinion of managers, supervisors, and employees are also taken into consideration. A, E, I, O, U, and X are used as symbols, where A means absolutely necessary, followed by E (Especially necessary), I (Important), O (Ordinarily important), U (Unimportant) and X (Undesired). The grid may also include number code that specifies the reasons for the ratings.

Thus it may seem a futile attempt to design a process layout when so many factors have to be considered in the planning process. But still, two factors tend to make it easier to plan for a process layout. One is the need for material or customers to move from work center to work center. Movement of material cost money, but it does not contribute to value addition of product. Cost of movement is directly associated with the distance moved. If this movement can be minimized, then unnecessary handling cost can also be minimized. Another factor is the need to reduce duplication of resources, wherever possible. If resources can be shared between departments, for example same supervisor for two departments, total investment on resources and facilities can be minimized. If the departments can be placed near each other than duplication of resources can be avoided. Thus, planners use flow patterns of material to minimize transport cost, distance traveled and time taken to move between work centers. This objective is achieved by bringing departments with high traffic as close as possible.

Discussion questions

1. What are the objectives of process layout?
2. How is distance minimizing layout procedure used in layout design?
3. Describe the steps of designing process layout.
4. Consider the layout of a retail store and a restaurant that you recently visited. What criteria seemed most important in their planning? Why?
5. What do you mean by servicecaping? Explain its different elements.
6. What are the most important factors taken into consideration when planning for an office.
7. Describe the different types of office layout.

Lesson Three: Designing Product Layout

Lesson Objectives
After completing this lesson you will be able to:

- Describe the steps of designing product layout
- Explain the special considerations of product layout

In the last lesson, we noted that the major task of the layout planner was to determine the location of departments that would minimize the movement of materials. In general, process focused organizations have to process hundreds of non-standardized products. Since the demand for each of the product is not high, it does not make economic sense to install different set of machines and tools for different products, rather the same set of machines are used for all the products. This ensures high utilization of both machines and workers at relatively low cost. For this reason the planner's problem is to determine where to locate all the machines and tools. The most logical approach is to group machines according to the nature of their work or processing activities. Once the machines have been grouped into departments the next step is to determine the best possible location of each department. Most planners solve this problem by analyzing the work flow pattern or the nearness priorities of the department.

In product layout the machines or activities in a facility are arranged according to the processing needs of the product. When the demand for a product is high, it makes economic sense to dedicate a set of machines exclusively for the product. The layout planner does not have to think in term of relative location of the activities, because they are predetermined by the processing needs of the product. In product layout the planner is interested in task splitting and line balancing. By identifying different sizes of tasks and different pace of work he tries to find the most efficient and productive layout.

Factors considered in Product Layout Design

A production line may contain only a few activities or may contain hundreds depending on the nature of product being produced. Product moves from one activity to another, until it is completed at the end of the production line. The activities are inter-dependent and the succeeding activity cannot be carried out until the preceding activity has been completed. The objective of assembly line is to achieve smooth flow of material through the facility with minimum idle time on the part of the machines or workers. Many of the benefits of the assembly line is derived from the ability to break-up tasks into small series of activities or tasks that can be performed quickly, routinely, and independently by low-skilled workers. Typically, the tasks may take as little as few seconds or at the most twelve to fifteen minutes. To obtain smooth utilization of resources (workers and machines), the activities are grouped into workstations, each station requiring the same amount of time to perform. To ensure smooth flow of material through the system, at a desired rate, with high utilization of workers and machines, the product layout designers have to take account of the following factors:

Product moves from one activity to another, until it is completed at the end of the production line.

(a) Task splitting
(b) Cycle time
(c) Line pacing
(d) Workers attitude and

(e) Line balancing.

(a) Task splitting: The production rate is as fast as the slowest workstation. For example, if a workstation require 15 minutes to complete all its tasks and all other stations require less than 15 minutes, then we would expect a completed product after every 15 minutes at the earliest. Assembly line achieves fast production rate by :

- *Breaking tasks* into a series of small tasks, such that, each task can be carried out independent of each other,
- *Sharing tasks,* such that, two adjacent workstations assist each other to complete the task, rather than each independently completing the whole task,
- *Using parallel workstations,* so that each workstation carryout the same task independent of each other, increasing the amount of flow through the bottleneck,
- *Redesigning product,* so that the task in question can be split into smaller tasks that will reduce the time required to complete the task, and
- *Using skilled labor and overtime,* so that, they either work faster or buildup inventory to feed tasks down the line.

(b) Cycle time: Cycle time is the maximum time allowed at each workstation to perform assigned set of tasks before the in-process product moves on to the next workstation. In an idle situation, a single worker mans each workstation. Cycle time determines the workload that a station can bear. On the other hand, cycle time depends on the desired output rate of the line. In turn, line efficiency varies with the cycle time selected. Inefficiency results from a workstation having excessive idle time than others. Managers always look for alternative cycle time that would reduce inefficiency and at the same time match desired output rate. While improving on efficiency, if there is mis-match between desired output rate and proposed output rate, managers compensate it by extending working hours, initiate overtime, add shifts or even go for parallel lines. Another approach is to pace work at a faster rate to build up inventory and then lower the rate to deplete the excess inventory.

Cycle time determines the workload that a station can bear.

(c) Line pacing: Pacing means the method or type of movement of materials and products from one workstation to the next. There are two type of pacing (i) paced line and (ii) unpaced lines. *Paced lines* are generally automated using some sort of conveyor belts. The belt moves at a constant speed, and the operators work on the products as they pass by their workstation. If the tasks are of long duration, the worker may have to walk alongside the conveyor, working on the product, and have to walk back to his/her station once the task has been completed. Too fast a paced line may result in unfinished tasks passed on to the next station. It also leads to frustration and dissatisfaction among the workers.

Line pacing means the type of movement of materials and products from one workstation to the next.

Unpaced lines use non-continuous, non-automated handling equipment like roller conveyors. The worker determines pace of work. However, the required daily output has to be fulfilled. Advantage of unpaced line is that workers can spend more time on difficult tasks and less time on easy tasks. They can also, if required, work fast for certain period of time, to build up in-process inventory, and then take longer break before starting the next task. But unpaced line requires more space to store in-process inventories and are

Unpaced line requires more space to store in-process inventories and are not suitable for heavy and bulky products

not suitable for heavy and bulky products. At the same time, when there are short and long duration tasks in the line it is difficult to maintain minimum output rate, resulting in down the line stations not having sufficient in process inventory reaching them on time. Imbalance in flow is very common in unpaced lines.

(d) Workers' attitude: Assembly line layout is said to de-humanize work environment. Workers get bored because of the monotony of low-skilled, repetitive works. Studies have shown that paced assembly line layout leads to increase in absenteeism, turnovers and accidents. Short cycle time lowers job satisfaction. Workers prefer buffer stocks to ensure more breathing space, which is not available in paced lines. Job enlargement and job rotations can increase variation in job and also reduce over specialization in one task. But some workers do not like to take up the additional responsibilities associated with enlargement and rotation. To increase job satisfaction, in addition to enlargement and rotation, the behavioral scientists propose forming workers groups, involving workers in decision making process, arranging facilities to ensure interaction of workers, creating multi-workers workstations, and recruiting workers who can work in groups.

(e) Line balancing: As stated previously, the total activities of a production line are split into small tasks. Some of the tasks would not take more than few seconds to accomplish whereas other tasks may take minutes to complete. Recruiting individual workers for each task would result in excessive number of employees with some workers having excessive idle time and others, in the same production line, with no free time. In order to reduce both the number of workers and inefficiency (idle time of some of the workers) the tasks are grouped together into workstations. Ideally, there would be equal amount of work at each workstation. Line balancing involves assigning tasks to workstations. One objective of line balancing is to minimize the total idle time at each workstation. The second objective is to minimize the number of workstations, thus, the number of workers. Line balancing procedure would be discussed, in more detail, in the next section.

Main objectives of the line balancing are to minimize idle time and to minimize number of workstations

Line Balancing Procedure

The objective of line balancing is to distribute all the tasks of the production line among the workstations so that each workstation do not have more than it can process neither do they have excessive idle time. The goal is to obtain well-balanced workload for all the workstations and at the same time have a minimum number of workstations in the production line.

The number of tasks that can be assigned to a workstation depends on the ability to split the tasks into very small activities and also on the cycle time. Cycle time, on the other hand, depends on the desired total output for a given period and on paced speed of the line. Number of workstations is governed by the cycle time of the system. Amount of task splitting and pacing is influenced by the workers' behavioral attitude. In other words, while balancing a line the designer does not only have to minimize the idle time and the number of workstations, but also have to balance between all the factors discussed so far. The general procedure to balance a line consists of the following steps:

1. *Determine the desired output for a given period:* Statistical forecasting techniques, along with market survey, are used to determine the demand for

Use the forecasting technique to determine short-time market need rather long-term demand to match with production output.

the product. Long term forecasting production planning does not provide the desired accuracy. Forecast for the next three or four months are more reliable for planning. The total demand for the period is then divided by the total number of production hours available in that period. This provides the required output rate per hour for the production line. For example, if the demand for a product is 5760 units per week, and if the facility operates one shift a day, 8 hours per shift, 6 days a week then the required output rate is 120 units (5760/(1x8x6)) per hour. One of the goals of line balancing is to match production line output rate with the output rate demanded by the market. Matching both ensures on-time deliver, small inventory and low probability of stock-outs. To match output rate with demand is not always appreciated by the managers. It requires frequent change in schedule, re-adjustment of workers' pace, or even may need redesign of work elements. The managers prefer a constant output rate so that when the demand is low the inventory builds up but is depleted when the demand rises.

This step analyzes all the activities that would be required to produce a complete product.

2. *Identify all the activities and split them into small tasks:* This step involves analysis of all the activities that would be required to produce a complete product. Both manual and automated activities are identified and listed. The listed activities are analyzed by using time and motion study. The information generated by the study is used to split activities into small independent tasks. For example, in a washing plant the activity of washing a trouser can be split into (i) put identification mark on the trouser, (ii) wash the trouser, (iii) dry the trouser, (iv) iron the trouser, (v) stack the trouser with other cloths of the customer, and (vi) shelve the stack for delivery.

The Precedence relationship of tasks depends on the nature of technology used.

3. *Identify the precedence relationship of tasks:* In our example of trouser washing, in step 2, a worker can iron the trouser only after the trouser has dried, or he can dry the trouser only after it has been washed. This dependence of tasks on completion of its predecessors' activity is called precedence relationship. This precedence relationship of tasks depend on the nature of technology used. Some technologies are very rigid and do not allow any variation in the relationship, whereas, there are others that do allow some latitude in the sequence of tasks. Once the precedence relationship of all the tasks have been identified and verified, a precedence diagram, very similar to PERT network, is constructed. The diagram gives a visual understanding of the relationship between the tasks. In the diagram, circles denote the tasks and arrows represent the direction of flow of the relationship. Time of performance of each task is shown below the circles.

4. *Determine the required cycle time:* The cycle time of a production line is calculated by using the following formula:

$$\text{Cycle Time} = \frac{\text{Production time per day}}{\text{Required output per day (in units)}}$$

As defined earlier, cycle time is the maximum time allowed for work on a unit at each workstation. Cycle time should be greater than the duration of the largest task in the production line, otherwise the workstation with the largest task would be a bottleneck, and the line would not reach the desired output rate. The cycle time should not only depend on the output rate, as suggested by the formula, but should take workers' attitude into consideration.

5. *Determine the theoretical minimum number of workstations:* Each workstation in the production line consists of a bundle of tasks assigned to it. A single worker, in general, operates each workstation. The worker is expected to carry out all the tasks assigned to the workstation. The objective of line balancing is, while maintaining the precedence relationship of the tasks, distribute the tasks among minimum number of workstations and at the same time minimize the idle time of the workstations. A perfectly balanced line is one in which none of the workstations have idle time nor do the sum of duration of tasks in the workstations exceeds the cycle time. By minimizing the number of workstations and idle time, management maximizes the productivity of the workers. In practice, because of variation in task time and inflexibility of precedence relationship, it is not possible to achieve a perfectly balanced line. The formula below gives the theoretical minimum number of workstations for production line:

$$\text{Theoritical minimum of workstations (TM)} = \frac{\text{Sum of total process time}}{\text{CycleTime}}$$

   Any resulting fraction value is rounded to the higher number. If only one worker is assigned to each workstation, then TM also specifies the number of workers required for the production line.

6. *Select a primary and a secondary rule by which to assign tasks to workstations:* Many methods have been proposed to assign tasks to workstations. None of them have been found to provide a perfectly balanced line. But still, a set of rules is needed to guide the selection of tasks to be assigned to a particular workstation. One simple rule is to select and develop a list only those tasks that either do not have any preceding task or all their preceding tasks have been assigned to a workstation. From the list select

   Select & develop a list of only those tasks that do not have any preceding task or the preceding tasks have been assigned to a workstation.

   - the task that has the largest time, as long as it matches the available time of the workstation, or
   - the task that has the highest number of succeeding tasks, or
   - the task that has the greatest sum of the task time of its successor tasks.

   One of these rules is used as the primary guide for selection of tasks and another is used to break the deadlock, if any tie arises.

7. *Assign tasks to workstations:* The number of assignable tasks can be too large and unwielding. Selecting tasks from the list for a workstation can become a problem unless some type of algorithm is used. Line balancing problems have been solved by the following approaches:

   - Trial and error
   - heuristic method
   - sampling technique
   - linear programming, and
   - dynamic programming

   Linear programming and dynamic programming are both optimization methods. The problem with these two methods is that they need large number of accurate information and considerable computation for even a small problem. Though, heuristic methods do not guarantee the best solution, still

they are more frequently used because they do provide acceptable solutions with less effort. Best approach is to use different heuristic methods on the same problem and select the best solution among them.

A simple heuristic method is explained here. This method will identify a task, assign it to a workstation, and check for the idle time of the workstation. This process is repeated till the idle time of the workstation is exhausted. the procedure is as follows:

(i) Create a workstation.

(ii) Create a list of assignable tasks such that

- the task has not been assigned to any workstation
- the task does not have any predecessor task or all of its predecessor tasks have been already assigned
- the processing time of the task is not greater than the idle time of the workstation

(iii) Use primary rule to pick a candidate. Assign the task to the workstation. If two or more tasks are tied then use secondary rule to choose the task.

(iv) Find idle time of the workstation. Idle time is equal to the cycle time less the cumulative total time of all the tasks assigned to the station. If the idle time

- is greater than zero, go to step (ii)
- is equal to zero, or less than the time duration of all the assignable tasks, go to step (i)

(v) If all the tasks have been assigned to different workstations, then stop.

8. *Compute efficiency of the system:* One measure of a good assignment of tasks is minimization of total idle time. Idle time statistics is as follows:

$$\text{Idle Time (ID)} = (n \times c) - \sum t$$

Where,

n = number of workstation
c = cycle time
$\sum t$ = Sum of time of all the tasks in the line

The line is perfectly balanced when ID = 0.
Efficiency is the ration of production time to total time. Efficiency statistics is as follows:

$$\text{Efficiency (E)} = (\sum t/nc) \times 100$$

Where, n, c, and $\sum t$ are same as that in Idle Time.

The degree, which a line approaches, a perfect balance is called balanced delay. Balance delay is found by: Balance Delay (BD) = 100 – E.

A well-balanced line has a very low balanced delay.

Other Balancing Considerations

In the preceding discussion on line balancing time was the only criteria used to assign tasks to workstations. In practice, the ability to develop a balanced line usually involves additional considerations. A list of other factors, which might be used in conjunction with time, is given below.

- *Workers skill requirement and wages:* If skill requirement of tasks were quite different, it would not be advisable to place the tasks in the same workstation. It is common practice to pay workers according to their skills. Cost may be kept down by having premium tasks performed by skilled workers and their valuable time not wasted by assigning them unskilled tasks.
- *Human factor and deliberate unbalanced line:* The assumption that tasks time are constant cannot be ensured where workers operate machines. Whenever humans are involved task completion time will vary. The magnitude of this variation differs from worker to worker, and even for the same worker it varies from day to day. The reasons for this variation are numerous, like fatigue, boredom, training, etc. This variation generally leads to buildup of works in the middle of the production line than at the front or end. Managers find it desirable to deliberately unbalance the line by having shorter cycle time in the middle. This deliberate unbalance helps to minimize chances of buildups in the middle. This high-low-high cycle time is known as "the bowl phenomenon".
- *Job Enrichment:* To motivate workers it may be worthwhile to group certain tasks into workstations, even though it may violet the precedence relationship and selection rules.
- *Task characteristics:* Incompatible tasks should not be assigned to the same workstation. Dirty tasks like painting and greasing may be assigned together, but painting and sanding should be separated.
- *Parts similarity:* Tasks using the same parts should be assigned the same workstation.
- *Equipment:* Tasks requiring the same equipment and tools should be assigned the same workstation.

Whenever humans are involved task completion time will vary.

Thus the product layout planner does not have the problems faced by that of process layout designer. Because, a product focused approach is adopted only when the organization deals with limited number of highly standardized product with very high demand. The demand for each type of product is so high; that it makes economic sense to install different sets of specialized machines dedicated to different products. Since each product has its own set of machines, the question of creating departments and locating them does not arise. The arrangement of the machines and tools are completely governed by the sequence of processing requirements of the product. Activities are like a chain; one following another without interruption, unlike process layout where activities are jumbled up and backtracking is very common. Product focused layout are also known as production line or assembly line arrangement.

Discussion questions

1. What information is needed before you can solve a line-balancing problem?
2. Why is employee dissatisfaction high in assembly line? What steps may help to alleviate this problem?
3. What are the different steps of line balancing procedure?
4. What factors are considered in line balancing?
5. What do you mean by a paced and an unpaced line?
6. Paced line increases stress of workers, but unpaced line increases the need for more space for inventory. How can both be reduced at the same time?

Lesson Four: Designing Hybrid Layout

Lesson Objectives
After completing this lesson you will be able to:

- Describe the need for hybrid layout
- List the characteristics of hybrid layout
- Explain the different types of hybrid layouts

Low demand and non-standardized products compels the organizations to arrange the activities of the facility according to process layout principals. Studies have recorded that in many process layout arrangements machine utilization is only 40% and rest of the time spent in either set-up of the machine or handling of the materials. Process layout has the following sources of costs that do not add value to the product:

- *Set-up cost:* Work has to be stopped frequently to re-tool or re-adjust the machines for the next batch of product.
- *Handling cost:* Small batch of products have to be moved from one workstation to the next, using variable path moving equipment.
- *Scheduling cost:* Products share machines and backtrack frequently. Scheduling the activities can be complex requiring frequent adjustment.
- *Opportunity cost:* Delays and bottlenecks are common. Opportunities are lost because of delays and long delivery time.

When a standardized product has high demand the activities can be arranged according to the need of the product. Product layout reduces both set-up and material handling costs. However it is very inflexible to change in product design and demand. Product layouts are also very unpopular with the workers. Sociologists complain that product layout de-humanize work and the workers. In this layout the total work is broken down into small and simple tasks. The workers are expected to repeat the same task many times during the whole working day. In a highly structured environment, product layout attempts to control each and every action of the worker. Workers feel intimidated and have low moral. They do not have any opportunity to acquire additional expertise and have no scope for advancement.

Hybrid layout is an attempt to overcome the excessive cost of set-up and material handling, as in process layout, and at the same-time tries to enrich the job, as in case of process layout. In simple term, hybrid layout brings together both the process layout and the product layout. When the demand for the product is not high enough to justify dedicating a set of machines for the single product, management can derive the benefits of product layout by creating product layout in some portion of the production system. Here, we are not concerned with the entire plant rather only a part of the total production system. Using the concept of group of operations or family of products the machines are arranged into cells. Individual member of the family may not have high demand but collectively they have the critical mass to justify dedicating machines for that part of sequence of operations. Individual members pass through the production facility in different sequences. But when a specific sequence of operations is required, which is common for all the members of the family, they come together in the cell and get

Hybrid layout is an attempt to overcome the excessive set-up cost & material handling cost, and tries to enrich job.

processed one after another. Large part of the facility remains process focused, only the machines in the cell are arranged according to product layout. For example, spare and parts of products may follow variable path in the production center, but when the products are assembled from parts, the parts come together in a cell where the activities are standardized and common for all products.

Major characteristics of Hybrid Layout

Experts on hybrid layout suggest the following characteristics:

a) *Layout types:* Both product layout and process layout are common in hybrid layout. Part of the facility is product focused and part process focused.

b) *Demand:* Demand for individual product or part is low, but for a family of products or parts it is quite high.

c) *Number of workers in cells:* Depending on the nature of the cell, a cell may be managed by a single worker or by a team of workers who work solely in the cell. A team of 6 to 15 is very common.

d) *Product:* Products are grouped together into a family or families according to their characteristics or similarity of sequence of processing needs.

e) *Equipment:* Special purpose machines are arranged into groups to be used for specific family of products. They are segregated from other machines of the facility.

f) *Output target:* At the beginning of the production period the members of the cells are given a common production target which they are to achieve by the end of the work period. As far as possible, they work independent of all other workers of the facility.

Activity: What are the major strategic differences you can identify between the Hybrid layout with others? Discuss.

Types of Hybrid Layout

Hybrid layout can be categorized into

(a) One Worker, Multiple Machine (OWMM),
(b) U-Line Cell,
(c) Group Technology (GT), and
(d) Flexible Manufacturing System (FMS).

All these variety of hybrid layout attempts to derive the benefits of product layout when the volume for demand for individual product is low. The basic assumption of these layouts is that the production facility handles more than one product. Each of them form independent cells of machines or activities, that is why, they are also known as cellular layout. A short description of each is given below.

(a) One Worker Multiple Machine (OWMM): When the demand for a product is low, a long production line cannot keep workers sufficiently busy, and utilization of both man and machine tends to be low (Figure 10.4.1). By keeping the production line short, which can be managed by a single worker,

managers can ensure high utilization of both worker and machines and at the same-time derive the benefits of flow-line operations. One Worker, Multiple Machine (OWMM), also know as Rabbit-Chase Cell, is an arrangement of machines where a single worker simultaneously operates several different machines. In most cases, the machines are arranged in a circle, facing the operator in the center. The machines are mostly automatic, and the operator moves around the circle, only to load and unload the machines. The product enters the circle at one end and leaves by the other end, achieving a line flow. The machines are not fixed to the floor, as such, their numbers can be increased or decreased in the circle. Even their relative position, within the cell, can be changed. This is very important because the same cell can be made to handle different product or part by simply changing the arrangement of the machines.

Keeping the production line short, managers can ensure high utilization of worker and machines together.

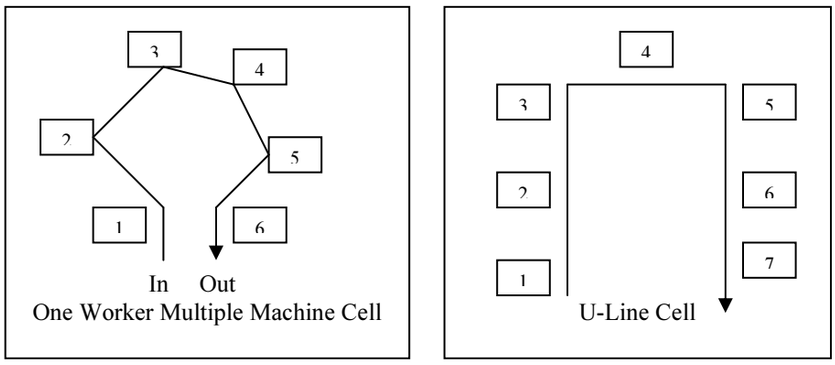


Figure 10.4.1: Example of OWMM and U-Line cell

OWMM reduces both inventory of work-in-process and labor. Labor requirement is reduced because a single operator is responsible for all the machines of a cell. Work-in-process inventory is reduced because of the line-flow nature of the cells, where products or parts do not have to wait in queue, rather move directly to the next operation within the cell. The only problem of OWMM is that the worker has to be more skilled than that is required in product layout arrangement. This is because the worker within the cell has to be skilled enough to operate all the machines in the cell.

(b) U-Line Cell: When the machines are arranged such that they form a U or a C, it is called a U-Line Cell (Figure 10.4.1). The basic features of U-Line Cell are similar to that of OWMM, but with one major difference. In OWMM the cell contains only one operator, but in U-Line Cell a team of workers operate the machines. In OWMM the number of machines are small so a worker can easily master the skill required to operate them. But, in case of U-Line, in most cases there are more machines and a single worker may not be able to operate them all or the production cycle time may be too long for him. For this reason, multiple of workers are teamed together into the cell, so that, each worker operates a set of the machines in the cell, leaving remaining machines for other members of the team to operate. U-Line reduces the skill requirement of the workers. More workers are added to the cell, each performing fewer operations. This arrangement also increases the throughput of the cells. Workers can work faster. But the problem in this type of arrangement is that the cell can be as fast as the slowest worker in the team.

Multiple of workers are team together into the U-line cell to capable each of the worker operates a set of the machines in the cell.

Objective of group technology is to find a group of products with similar sequence of process-requirements & reducing the number of machine set-ups.

(c) Group Technology (GT): Group Technology is a method of sorting products into families based on similarity of their design characteristics or processing needs (Figure 10.4.2). Design characteristics include size, shape, functions or raw material usage. Processing needs involve the type and sequence of operations required. The objective of group technology is to find a group of products with similar sequence of processing requirements and reducing the number of machine set-ups. It achieves some of the economics of product layout without having to standardize all the products. A good example is bolts of different shapes and sizes can be grouped into a family, because regardless of their sizes and shapes all bolts require the same raw material and same sequence of operations, thus reducing the need to re-tool or re-adjust the machines.

Two basic steps are involved in applying group technology. The first step is to identify the products that can be grouped into families. Design specifications of all the products or parts are rigorously checked to find similarity of characteristics like shape, size, etc. Next distinct groups are identified. The second step is to arrange machines into cells, so that each cell can process a particular family of product as identified in the first step. The result is many small independent plants in the larger plant.

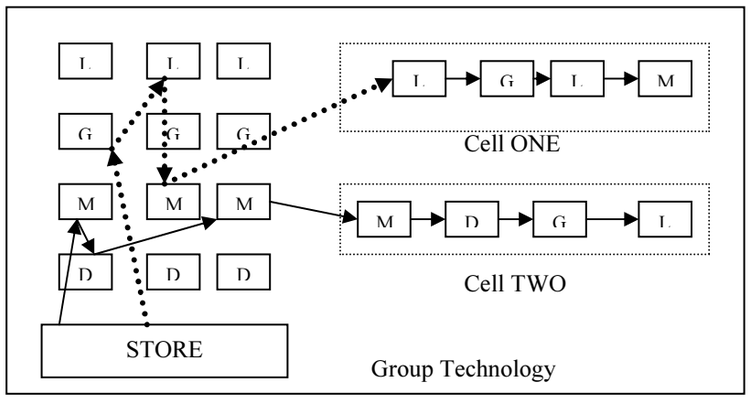


Figure 10.4.2: Example of group technology

Once implemented, group technology can reduce the number of set-ups and set-up time in the cells. It makes planning, routing, scheduling and controlling of jobs easier. It results in low or no work-in-process inventory. Because of the compact arrangement of machines it reduces material handling and the cost associated with it. It also results in shorter production cycle time. It contributes to quality by reducing rejects or reworks. Finally, it increases the opportunity to automatic machines in the production facilities. But the managers should apply group technology with caution. It is time consuming and expensive to convert a process layout into a cell layout. At times it is not at all cost effective to adopt group technology.

(d) Flexible Manufacturing System (FMS): When need arises to operate on a large variety of parts or products, typically around 100 different products, and each part or product have small volume, typically 40 to 2000 units per part per annum, completely automated group technology is the answer to the production problem. Flexible Manufacturing System is a computer controlled

automatic version of Group Technology. In Flexible Manufacturing System semi-independent cells of automatic machines, controlled by computer, automatically loads, processes, and unloads products with little or no human intervention. With no labor involvement the machines can easily be worked for long hours. These systems are very expensive, but they achieve benefits of product layout with small batch sizes and greater flexibility. Like product layout it can also handle high volume with low variety of products. In addition, it can easily be reprogrammed to process different products at different times. This flexibility is appreciated by product focused managers who has to deal with products with short life cycle.

Flexible manufacturing System is a computer controlled automatic version of Group Technology.

A typical Flexible Manufacturing System contains (a) several computer-controlled work cells where the machines are capable of carrying out their own operations and set-ups, (b) a computer-controlled material handling system that can move work from machine to machine in random order at the correct time and correct posture, and (c) loading and unloading stations. Workers are only responsible to bring raw materials of a family of parts to the loading station and remove finished products from the unloading station. Rest of the work is done automatically by the machines. The transporter automatically moves the material to different machines in the cell, in a predetermined sequence. The machine load the material, operates on it, and off-loads it on the transporter, which moves it to the next machine or to the unloading station. The computer controls the routes of different parts, through the cell. Machines commonly used in FMS are Industrial Robots, Automatic Guided Vehicle (AGV), Automatic Storage and Retrieval Machines (AS/RS), Computerized Numerically Controlled Machines (CNC), etc. It is very expensive to adopt Flexible Manufacturing System. Initial investment can be in between $ 5 million to 25 million. It requires a through analysis of the demand pattern of the products for the next 5 to 8 years and the future objective of the company. Otherwise the system may become an embarrassment for the management. Where labor is cheap and readily available the cost of the system can not be justified.

Discussion questions

1. What are the characteristics of a good FMS system? Why is the system called flexible?
2. What are the characteristics that a product may possess to make it a good candidate for automation?
3. What do we mean by hybrid layout? What benefits can we expect from a hybrid layout?
4. What is OWMM concept? What is a Group Technology? How do they differ?
5. Describe the different formats of hybrid layout? What are the primary differences between OWMM and U-Line Cell?
6. Explain the major characteristics of Group technology.

Hightec, Inc.

Case Analysis

"It's hard to believe," thought Glenn Moore as he walked into the employee lunch area, "that it has been only six years since I founded Hightec." He was not interested in lunch because it was only 9:30 A.M. His purpose was to inspect the new microcomputer, which had just been purchased to improve management of the company's inventory and accounting functions. The computer had to be housed at the rear of the employee lunch area, right next to the coffee, hot soup, and hot chocolate vending machines. There was absolutely no room for the computer elsewhere.

Hightec is a manufacturer of transducers, which convert gas or liquid pressure into an electrical signal. Another form of the device converts weight or force into an electrical signal. A typical customer order is for only 3 to 10 units. The firm currently rents a 12,000 square feet, L-shaped building housing four basic sections: the office area, an engineering area, a machine shop, and an assembly area. The 80 employees comprise machinists, engineers, assemblers, secretaries, and salespeople. Although Moore concentrated on finance and marketing during the first two years of Hightec's existence, his activities now are more concerned with production costs, inventory, and capacity. Sales have been increasing about 30 percent per year, and this growth is expected to continue. Specific symptoms of Hightec's problems include the following:

- Space limitations have delayed the purchase of a numerical control machine and a more efficient testing machine. Both promise greater capacity and higher productivity, and their costs are easily justified.
- The machine shop is so crowded that equipment not in constant use had to be moved into the inventory storage area.
- More machines are being operated on second and third shifts than would normally be justified. Productivity is falling, and quality is slipping.
- Approximately 10 percent of the work-force's time is spent moving materials to and from the inventory storage area, where inventory at all stages of production is kept. The chaotic supply room makes finding wanted parts difficult, and considerable time is lost searching.
- Approximately 1000 SF of storage space must be rented outside the plant.
- Lack of capacity has forced Moore to forgo bidding on several attractive jobs. One salesperson is particularly disgruntled because she lost a potentially large commission.
- Several office workers have complained about the cramped quarters and lack of privacy. The quality of employee space also leaves an unfavorable impression on prospective customers who visit the plant.
- Additional help was just hired for the office. To make room for their desks, Moore had to discard his favorite tropical plant, which started as a cutting when Hightec was formed and had sentimental value.

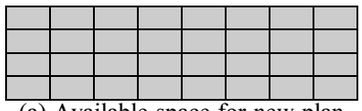
The Options

Gleen Moore has identified three options for increasing capacity at Hightec. The first is to renew the rental contract on the current facility for another five years and rent portable units to ease the cramped conditions. He discarded it as being inadequate for a growing problem. The second option is to purchase land and build a new 19,000 square foot facility. The most attractive site would cost $100,000 for land, and the construction cost is estimated at $40 per square foot. His cost of capital is about 15 percent. The third option is to renew the rental

contract on the current building for another five years and rent an adjacent 7000 square foot building only 30 feet from the current one. The rental cost of both buildings would be $2800 per month. Choice of this third option would necessitate building a $15,000 corridor connecting the buildings. However, Moore estimates the relocation costs (such as for moving and installing the machines and the loss of regular-time capacity) to be $20,000 less than with the second alternative.

The Layout

Regardless of which option Moore chooses, he must improve on the existing layout. It suffers in terms of materials handling costs and departmental coordination. When Moore initially designed it, he located the office first and then fit the other departments around it as best as he could. The main consideration for the other departments was not to have the machine shop next to cleaning room. Moore put together the information needed for planning the new layout, as shown in Table and Figure below. The projected area requirements should be sufficient for the next five years. Both layouts provide for 19,000 square feet. The REL chart emphasizes materials handling and communication patterns.



(a) Available space for new plan (option 2)

(b) Available space for renting building (Option 3)

Glenn Moore walked back to the office with a fresh cup of coffee in his hand. He hated hot chocolate, and it was too early for soup. He wondered what he should do next. Whatever the choice, he wanted a more attractive work environment for the engineering and materials-management staffs, currently located in a cramped, open-office setting. Attracting creative people in these areas had been difficult. He made a mental note that the adjacent building also is quite drab.

REL Chart

		Closeness Rating Between Departments															Area Needed (blocks*)
	Department	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	
01	Admin. Office	-	I	A	E	U	A	E	O	O	O	O	I	E	O	U	3
02	Conference Room		-	U	U	U	U	U	U	U	U	U	U	U	U	U	1
03	Engineering			-	I	U	U	O	A	E	E	I	E	E	U	O	2
04	Production Manager				-	U	A	A	A	A	A	I	I	E	O	A	1
05	Lunch Room					-	U	U	U	U	U	U	U	U	U	U	2
06	Computer						-	A	X	U	U	U	O	I	U	U	1
07	Inventory Storage							-	A	O	O	O	O	U	U	U	2
08	Machine Shop								-	A	X	I	O	U	U	I	6
09	Assembly Area									-	A	A	I	U	I	A	7
10	Cleaning										-	O	O	U	U	U	1
11	Welding											-	O	U	U	U	1
12	Electronic												-	E	U	U	1
13	Sales/Accounting													-	O	U	2
14	Shipping/Receiving														-	U	1
15	Load test															-	1

**Each block represents approximately 595 square feet*

Case questions

1. Which expansion option would you recommend to Glenn Moore? Justify your position.
2. Design an effective block plan and evaluate it. Cite any qualitative considerations that you believe make your design attractive.

Source: Operations Management – Strategy and Analysis, Lee J. Krajewski and Larry P. Ritzman, 5th edition, Addison-Wesley Publishing Co., Inc., pages 448 to 449.