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ANALYSIS AND DESIGN OF PLANT LAYOUT FOR INDUSTRIAL PRODUCTION

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INTRODUCTION

Plant layout is the methodical arrangement of a firm's substantial facilities to improve the efficient use of machines, equipment, material, workers and the energy. It can also be defined as the sketch or act of planning a perfect facility arrangement, which include storage space, equipment, workers, inventory flow, machines and other services that develop production, beside the design of an efficient composition to have room for the facilities.

A high-quality plant layout is designed to present competitive advantage to manufacturers by enhancing the flow processes of information and inventory, thereby leading to diminution in manufacturing cost and enhanced productivity. "The production efficiency of a manufacturing unit depends on how well various machines, flow paths, storage facilities, and employee amenities are located in the plant." They observed that a systematically designed plant layout will guarantee a smooth and rapid movement of material from the raw material stage to the end product stage.

Slight adjustments in the position of machines and equipment in a manufacturing plant can significantly alter the easy flow of materials; this also alters the production costs and efficiency of the whole manufacturing process. The incapability to get manufacturing processes accurate leads to inflexibility, inefficiency, excess inventory, low product quality, delays, high costs and unsatisfied customers. Modifying an ineffective plant layout is quite expensive; hence the need to design a functional plant layout right from the starting is necessary.

To produce high quality products that will meet the customer demands, it is important to concurrently produce a number of products, to enable small volume products to be fashioned alongside others, thereby easily accommodate volume and product mix variations. In today's manufacturing a layouts must demonstrate ample robustness and flexibility regardless of invariable changes in operating requirements. This explains why proper plant layout design has turned out to be a crucial basis of existing industrial facilities, thereby enhancing the effectiveness of product outputs.

FACTORS THAT DETERMINE THE DESIGNING OF PLANT LAYOUT

The basic goals of designing plant layouts are to attain a minimum amount of materials handling, minimize machine interference, reduce bottlenecks and also enhance throughput, flexibility, employee's morale and safety. To attain optimum layout effectiveness when crafting a plant layout many factors of operation need to be critically considered.

The factors include the following:

(1) **Maximum accessibility:** The maintenance and repairs sections should be made readily accessible. This implies that machines and equipment must not be placed against the walls in order to ensure that servicing and maintenance operations are easily done.

(2) **Safety:** As the magnitude of safety in all human endeavors should not be overemphasized, a good plant layout should be made to function resourcefully and ensure that the accidents and its causes are reduced to the barest minimum.

(3) **Efficient utilization of space:** This entails the provision of adequate space around the traffic lanes and machines, as well as ensuring that sufficient spaces are made readily available for storage points within the facility location.

(4) **Maximum flexibility:** High-quality plant layout should be easily modified in order to meet up with the ever changing demands of the market and customer.

(5) **Room for future expansion and adjustments:** At the beginning plant layouts should be planned to be easily changed or expanded in line with ever-changing market and needs of manufacturing. This will make sure that the flexibility is attained in the facility in order to lessen the set up time required in the manufacturing of dissimilar products and also to attain the required throughput.

III. TYPES OF PLANT LAYOUT

(1) Process/Functional Layout: Process or functional layouts are very suitable for applications where the products that are obtained from raw materials and work-in progress entail high variations while dealing out the individual operations. The layout which is designed to stimulate the processing of activities that need several value additions is widely adopted, if the operation's system requires a large amount of products in small volumes. It is very useful in situations where the production process is planned in batches as the different product are organized to move from one area to another, based on the succession of operations that are earlier established. The Process layout group's workstations together according to the actions being performed regardless of which products each workstation is working on. Here the workers and machines needs to perform similar function that are assigned in the same place, also the distance between the sections should be very close to reduce the waste of materials handling and movements. The machine shop is a best example of a process layout, as it has various departments for milling, boring, and pressing operations, which make sure that imbalances present in one of the section is not allowed to obstruct in other sections, thereby achieving enhanced utilization of the available equipment and machines.

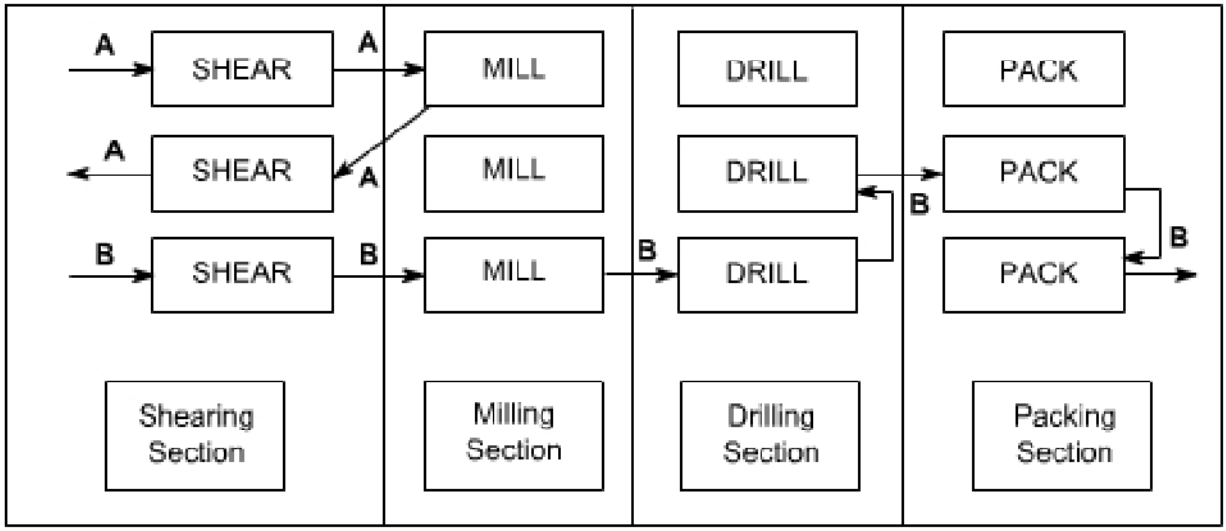

Figure 1: A Pictorial Representation of Process Layout. Source (NPTEL).

(2) Product/Line Layout: Product layouts which has miniature cycle of manufacturing with compact material handling is a type of plant layout where equipment, machines and workers are organized in a line based on the operation's progression needed for the product. Here equipment and machines are grouped

together, thereby enabling inventories and raw material to flow sequentially in an easy and clear to control manner from one machine to another as values are being further added on them. A good example of product or Line layout is the automobile assembly line which entails the movement of nearly almost all types of similar models in the equivalent operation sequences. The plan to be chalked out before designing a product layout include the sum of the required cycle time, the number and the array of the various manufacturing processes, and how to tackle the time variations for the different processes, and also the need to efficiently balance the layout.

Here the cycle time is calculated as: $\frac{available\ time}{number\ of\ products\ to\ be\ processed}$

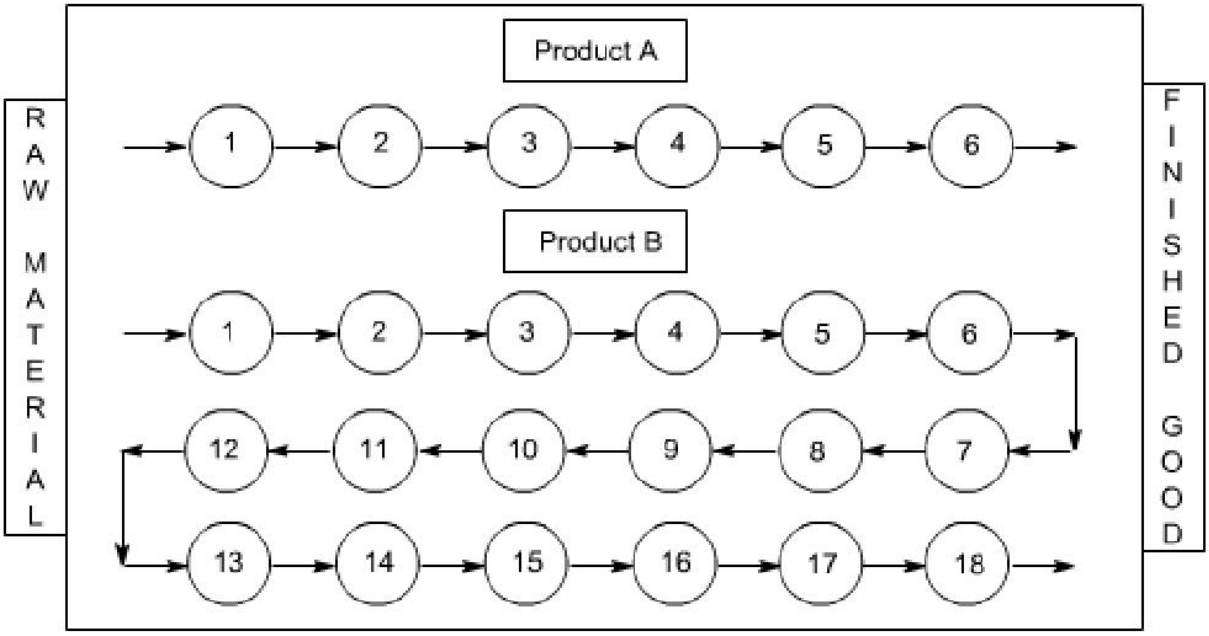

Figure 2: A Pictorial Representation of Product Layout. Source (NPTEL).

the plant layout type in which the equipment, machines, and workforce are transported to the site of the chief product to be produced. It is used in the manufacture of fragile or bulky projects like, space rockets, aircrafts, bridges, ships, flyovers, dams, road construction and buildings. The Fixed Position layout is very flexible and can accommodate changes in design and production processes and it also saves cost and the time involved in continual movement of work from one location to another and it is also very economical as jobs at different levels of finishing point can be produced concurrently.

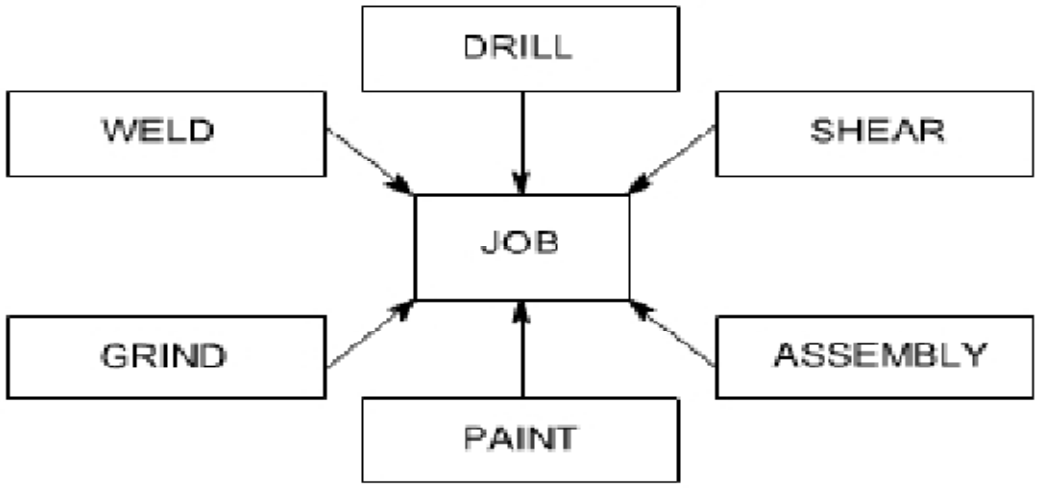

Figure 3: A Pictorial Representation of Fixed Position Layout. Source (NPTEL)

IV. ANALYTICAL CALCULATIONS OF WORK IN PROGRESS AND EFFICIENCY IN PLANT LAYOUT DESIGN

Surplus work in progress inventory in the shop floor is a chief waste that bedevils most of the manufacturing facilities; a good plant layout should make sure that the wastage of time is reduced to the barest minimum in order to improve the firm's profitability; to achieve the above the some of the following inputs should be known at the design stage:

- The speed of the transporting system (like the conveyor) in the plant, and the machines processing time for each product.
- The number of available space for the mounting of the machines.
- The number of machines to be installed.
- The quantity of the expected products, the customers' demand for the products.

The analytical calculation of work in progress of inventory is embedded on the queuing network theory. Hence the expected work in progress in a unit or department is given as:

$$E(WIPi) - \frac{p_i(c_{ai^2}+c_{si^2})gi}{2(1-p_i)}p_i \quad \text{..... (1)}$$

Where: c_{ai}^2 is the squared coefficient of variation of job inter-arrival,
p_i is the average utilization of department 1.
c_{si}^2 is the is the squared coefficient of variation of job processing time.
g_i is the coefficient of department 1.
Also, the expected work in progress in plant conveyor is given by:

$$E(WIPt) - \frac{\left(c_{at^2}+c_{st^2}\right)gt}{2(1-p_t)} + p_t \quad \text{..... (2)}$$

Here: p_t is the conveyor utilization.
c_{st}^2 is the squared coefficient of variation of the expected travel time per transfer of material.
c_{at}^2 is the squared coefficient of variation of job inter-arrival at the conveyor.
g_t is the conveyor coefficient.

Therefore the expected work in progress inventory for the plant will be:
E (WIP) = ΣE (WIPi +WIPt) …….. (3)

Also if F_{ij} is the amount of flow in loads between two units/departments i and j;
And D_{ij} is the distance in meters between two units/departments i and j;
C_{ij} is the cost per travelled distance between two units/departments i and j;

The efficiency of all the layouts can be calculated as:

Layout Efficiency = $\Sigma F_{ij} D_{ij} C_{ij}$ ……. (4)

V. CONCLUSION

The overall success of modern manufacturing facilities is attached on the capacity to efficiently and well design, maintain and run plant layouts that can easily adapt to the various technological changes, as well as the customer demands. Due to ever changing market requirements, unbendable competition, more multiplicity of products, concentrated life cycle of products, and soaring cost of manufacturing, companies or industries that have just one product may find it hard to break even.

This explains the necessity to have a well designed functional plant layout that will be capable to switch from one line of product to another with minor alterations. It will also attain fast flow of work in progress and raw materials including inventories at the lowest cost and with the lowest amount of managing as values are being further added to the product from the unloading of raw materials to the shipment of the throughput.

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