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Studies on Lucrative Process Layout for Medium Scale Industries

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Abstract**—**In this paper a comprehensive review on various factory layouts has been carried out for designing a lucrative process layout for medium scale industries. Industry data base reveals that the end product rejection rate is on the order of 10% amounting large profit loss. In order to avoid these rejection rates and to increase the quality product production an intermediate non-destructive testing facility (INDTF) has been recommended for increasing the overall profit. We observed through detailed case studies that while introducing INDTF to medium scale industries the expensive production process can be avoided to the defective products well before its final shape. Additionally, the defective products identified during the intermediate stage can be effectively utilized for other applications or recycling; thereby the overall wastage of the raw materials can be reduced and profit can be increased. We concluded that the prudent design of a factory layout through critical path method facilitating with INDTF will warrant profitable outcome.

Keywords**—**Intermediate Non-destructive testing, Medium scale industries, Process layout design.

I. Introduction

IN any industry the layout planning is determined by the best physical arrangement of resources within the available facility. The layout planning is important because it eliminates unnecessary costs for space and materials handling, reduces work-in-process inventory, produces goods and services faster, reduces distances that workers must travel in the workplace, improves communication and morale, increases retail sales, and improves overall brand image. Factory layout design is a multidisciplinary, knowledge-intensive task that is of a vital issue to the survival of manufacturers in today's globally competitive environment. There are different types of layouts, viz., process layouts, product layouts, hybrid layouts, fixed position layout, cellular layout etc. Process Layout is normally used in project and batch manufacturing (intermittent processes) industries. It is also used in department stores, offices, hospitals, and universities. Process layouts enable to make or sell a variety of products. It uses general purpose resources. Evidently it requires less automation than in product layouts. However, many industries reveal that the material handling costs per unit for process layout are higher than in product layouts. Note that scheduling production is more complex for process layout than in product layouts. Therefore it is desirable rather inevitable to have a lucrative process layout for any type of industry. In manufacturing engineering, process layout is a design for the floor plan of a plant, which aims to improve efficiency by arranging equipment according to its function. The production line should ideally be designed to eliminate waste in material flows, inventory handling and management.

In this paper we are focusing on lucrative process layout for medium scale industries using critical path method (CPM). Note that CPM has been widely applied in managing complicated projects in real world applications. Shih-Pin Chen and Yi-Ju Hsueh [1] reported a simple approach to fuzzy critical path analysis in project networks, which is used in this paper for optimizing the process layout. The idea is based on the linear programming (LP) formulation and fuzzy number ranking method. The fuzzy critical path problem is formulated as an LP model with fuzzy coefficients of the objective function, and then on the basis of properties of linearity and additivity, the Yager's ranking method [2] is adopted to transform the fuzzy LP formulation to the crisp one which can be solved by using the conventional streamlined solution methods.

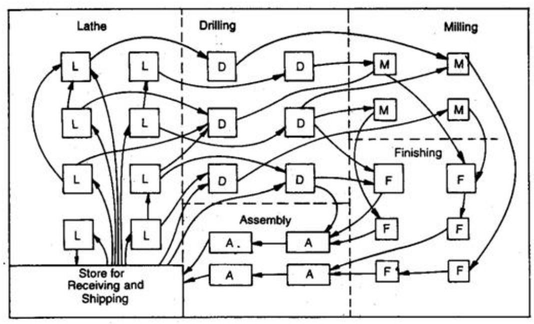

Fig. 1 A typical process layout

II. Literature Review

In process layout, the work stations and machinery are not arranged according to a particular production sequence. Instead, there is an assembly of similar operations or similar machinery in each department (for example, a drill department, a paint department, etc.). Fig. 1 shows a typical process layout. A lucrative plant layout is one way to reduce the cost of manufacturing and increase the productivity. Also increases good workflow in production route [3]. It was reported by many industries that there were wasted time or delay in manufacturing and as a result the movement of the

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material in long line and created the interrupted flow as well as the unproductive utilization of the plant area.

The facilities layout design refers to the arrangement of all equipment, machinery, and furnishings within a building envelope after considering the various objectives of the facility. The layout consists of production areas, support areas, and the personnel areas in the building [4]. The need for facilities layout design arises both in the process of designing a new layout and in redesigning an existing layout. The need in the former case is obvious but in the latter case it is because of many developments as well as many problems within the facility such as change in the product design, obsolescence of existing facilities, change in demand, frequent accidents, more scrap and rework, market shift, introduction of a new product etc. Product layout is generally used in systems where a product has to be manufactured or assembled in large quantities. In product layout the machinery and auxiliary services are located according to the processing sequence of the product without any buffer storage within the line itself.

In a process layout, (also referred to as a job shop layout) similar machines and services are located together. Therefore, in a process type of layout all drills are located in one area of the layout and all milling machines are located in another area. A manufacturing example of a process layout is a machine shop. Process layouts are also quite common in non-manufacturing environments. Examples include hospitals, colleges, banks, auto repair shops, and public libraries [5]. The advantages of process layouts are better machine utilization, highly flexible in allocating personnel and equipment because general purpose machines are used, diversity of tasks for personnel, greater incentives to individual worker, change in product design and process design can be incorporated easily, more continuity of production in unforeseen conditions like breakdown, shortages, absenteeism.

Facility layout refers to the arrangement of machines, departments, workstations, storage areas, aisles, and common areas within an existing or proposed facility. Layouts have far-reaching implications for the quality, productivity, and competitiveness of a firm. Layout decisions significantly affect how efficiently workers can do their jobs, how fast goods can be produced, how difficult it is to automate a system, and how responsive the system can be to changes in product or service design, product mix, and demand volume. The basic objective of the layout decision is to ensure a smooth flow of work, material, people, and information through the system. Effective layouts also minimize material handling costs; utilize space efficiently; utilize labor efficiently; eliminate bottlenecks; facilitate communication and interaction between workers, between workers and their supervisors, or between workers and customers; reduce manufacturing cycle time and customer service time; eliminate wasted or redundant movement; facilitate the entry, exit, and placement of material, products, and people; incorporate safety and security measures; promote product and service quality; encourage proper maintenance activities; provide a visual control of operations or activities; provide flexibility to adapt to changing conditions.

Process layouts are found primarily in job shops, or firms that produce customized, low-volume products that may require different processing requirements and sequences of operations. Process layouts are facility configurations in which operations of a similar nature or function are grouped together. As such, they occasionally are referred to as functional layouts. Their purpose is to process goods or provide services that involve a variety of processing requirements. A manufacturing example would be a machine shop. A machine shop generally has separate departments where general-purpose machines are grouped together by function (e.g., milling, grinding, drilling, hydraulic presses, and lathes). Therefore, facilities that are configured according to individual functions or processes have a process layout. This type of layout gives the firm the flexibility needed to handle a variety of routes and process requirements. Services that utilize process layouts include hospitals, banks, auto repair, libraries, and universities.

Process layouts, also known as *functional layouts*, group similar activities together in departments or work centers according to the process or function they perform. A process layout is characteristic of intermittent operations, service shops, job shops, or batch production, which serve different customers with different needs. The volume of each customer's order is low, and the sequence of operations required to complete a customer's order can vary considerably. In this paper we are focusing mainly on process layout for medium scale manufacturing industries.

The equipment in a process layout is general purpose, and the workers are skilled at operating the equipment in their particular department. The advantage of this layout is flexibility. The disadvantage is inefficiency. Jobs or customers do not flow through the system in an orderly manner, backtracking is common, movement from department to department can take a considerable amount of time, and queues tend to develop. In addition, each new arrival may require that an operation be set up differently for its particular processing requirements. Although workers can operate a number of machines or perform a number of different tasks in a single department, their workload often fluctuates from queues of jobs or customers waiting to be processed to idle time between jobs or customers. These are succinctly reported in open literature [1]-[17].

In a product industry, during the processes there are possibilities of getting defective products. In most of the industries without knowing the intermediate defects, the subsequent operations will be carried out and those defects are detecting and further rejecting the defective products only during the quality check at the outlet. Obviously this will invite unwarranted expenditure to any industry. Industry data base reveals that the end product rejection rate is on the order of 10% amounting large profit loss. In order to avoid these rejection rates and to increase the quality product production an intermediate non-destructive testing facility (INDTF) has been recommended using CPM for the selected industries for increasing the overall profit.

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III. Data Collection and Analyses

The data were collected from the local industries and the number of tools/equipment for manufacturing was counted in terms of the direction for raw materials and product in each industry. The operation process charts, flow of material and activity relationship charts have been used in the analysis. The problem of the each plant was determined and analyzed through systematic layout planning (SLP) method to plan the relationship between the equipment's and the area [3]. This method provides the new plant layout that improves the process flow through the plant, and help to increase space in industries. Based on the data such as product, quantity, route, support, time and relationships between material flow from – to chart and activity relation chart are displayed. From the material flow and relationship activity in production, the relation between each operation unit can be observed.

The first stage in any production process starts from foundry. During the production process rejection occurs, due to certain non-linear causes and effects, in both internal as well as external defects crept in certain products, which are usually identified only at the end of the production process using the conventional quality checkup. These end product rejections lead to huge profit loss. In order to avoid these types of wastage of time and cost many techniques are proposed by the earlier investigators. Medium scale industry data base reveal that the idle time between two processes are larger than the quality check and/or non-destructive test (NDT) time. Therefore we are recommending for reducing the rejection rate by utilizing the idle time for quality check before the subsequent process begins. This will facilitate for identifying the defective products early for recycling or using it for different product without increasing the total production time. As a result, wastage of time on machining the defective products can be minimized and profit can be increased.

Industry data base reveals that properly introducing intermediate NDT can possibly achieve less rejection rate. NDT is an analysis technique used in industries for identification of defective products. Mostly the NDT are carried out at the final stage of the production process where all the defective products are found out and rejected from shipping. There are many types of NDT facilities in various industries, which are depending on the nature of the material used for the production process. The most commonly employed techniques are radiographic testing, ultrasonic testing, liquid penetrant testing, magnetic particle inspection etc.. The data collected from various industries are summarized in Tables I-III. The most commonly occurred defects and the corresponding NDT used for the identification of the defects are shown in Tables I and II. As a case study, the time line chart for the production of ball valve body is shown in Table III.

TABLE I
Type of NDT Commonly Used for Surface Defect Detection

Sl. No.	Surface Defects	NDT
1	Blow	Liquid penetrant method, Magnetic Particle Inspection
2	Scar	Liquid penetrant method, Magnetic Particle Inspection
3	Blister	Liquid penetrant method, Magnetic Particle Inspection
4	Drop	Liquid penetrant method, Magnetic Particle Inspection
5	Scab	Liquid penetrant method, Magnetic Particle Inspection
6	Penetration	Liquid penetrant method, Magnetic Particle Inspection
7	Buckle	Liquid penetrant method, Magnetic Particle Inspection

TABLE II
Type of NDT Commonly Used for Internal Defect Detection

Sl. No.	Internal Defects	NDT
1	Blow holes	Radiographic testing, Ultra sonic testing
2	Porosity	Radiographic testing, Ultra sonic testing
3	Pin holes	Radiographic testing , Ultra sonic testing
4	Inclusions	Radiographic testing, Ultra sonic testing
5	Dross	Radiographic testing, Ultra sonic testing

TABLE III
Time Line Chart for Ball Valve Body

Sl. No.	Department	Number of Days
1	Pattern receipt on	0
2	Pattern inspection on	1
3	Methoding and Mounting on	6
4	Planning On	1
5	Pouring On	1
6	Knockout On / Cutting On, Intermediate NDT	1
7	Heat treatment On	1
8	Fettling On	1
9	Casting dimension On	2
10	MPI On, Final Inspection On	1
11	RT On	2
12	Repair On	1
13	Stress relived On	1
14	Dispatch On	1
	TOTAL NO OF DAYS	20

IV. Results and Discussion

Process layouts in manufacturing firms require flexible material handling equipment (such as forklifts) that can follow multiple paths, move in any direction, and carry large loads of in-process goods. A *forklift* moving pallets of material from work center to work center needs wide aisles to accommodate heavy loads and two-way movement. Scheduling of forklifts is typically controlled by radio dispatch and varies from day to day and hour to hour. Routes have to be determined and priorities given to different loads competing for pickup. Fig. 2

shows the proposed centralized NDT facility for reducing the rejection rate.

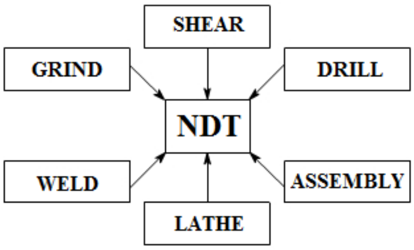

Fig. 2 A proposed flow chart with centralized NDT facility for reducing rejection rate

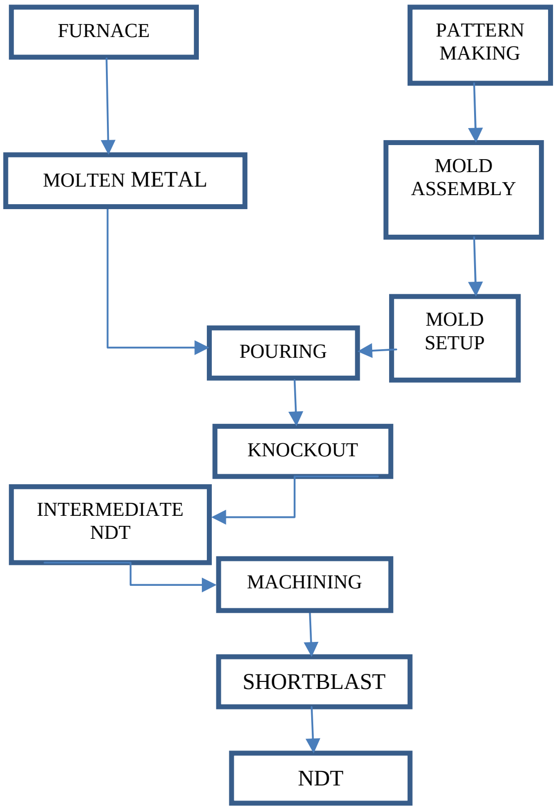

Fig. 3 The proposed flowchart with INDT for reducing rejection rate

Fig. 3 shows the proposed flowchart with INDT facility for reducing the rejection rate, which is more profitable than other layouts. It is evident from Figs. 2 and 3 that material storage and movement time are directly influenced by the type of layout. Storage space in a process layout is large to accommodate the large amount of in-process inventory. The factory may look like a warehouse, with work centers strewn between storage aisles. In-process inventory is high because material moves from work center to work center in batches waiting to be processed. Finished goods inventory, on the other hand, is low because the goods are being made for a particular customer and are shipped out to that customer upon completion. Improving the process layouts involves the minimization of transportation cost, distance, or time. Importance generally is based on the shared use of facilities, equipment, workers or records, work flow, communication requirements, or safety requirements. The departments and other elements are then assigned to clusters in order of importance.

In the open literature the popularly designing process layouts reported in three steps and are adopted here *in toto*.

Step 1. Gather information: Space needed, space available, importance of proximity between various units.

Step 2. Develop alternative block plans: Using trial-and-error or decision support tools.

Step 3. Develop a detailed layout: consider exact sizes and shapes of departments and work centers including aisles and stairways. Tools like drawings, 3-D models, and computer-assisted design (CAD) software are often used.

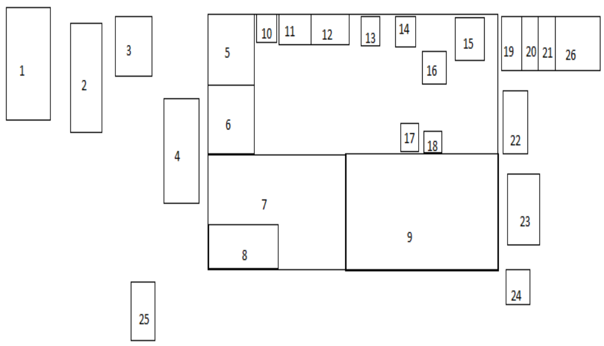

Fig. 4 The proposed process layout of a medium scale industry with intermediate NDT facility

TABLE IV
FACILITY LOCATION CHART

Area No.	Facility	Area No.	Facility
1	Pattern store	14	Heat treatment
2	LAB	15	INDT
3	Cooling tower	16	Quenching Tank
4	Scrap storage	17	Mixer
5	Surface dimension	18	Core sand mixer
6	Furnace	19	Grinding
7	Dispatch area	20	Welding
8	Scraps	21	Short blast
9	Sand yard	22	Knockout
10	Laddle pre-heater	23	Tank
11	Pattern Storage	24	Oxygen tank
12	Core storage	25	CO2 Storage
13	Core Production	26	Final NDT

Fig. 4 is the proposed process layout representing the change of molten metal into a complete product at the final stage without any defect with the help of an intermediate NDT facility prudently commissioned between knockouts and hardening processes. Facility location corresponding to Fig. 4 is shown in Table IV. Note that in addition to the low cost benefit, the main advantages of these type of process layouts include: flexibility - the firm has the ability to handle a variety of processing requirements, motivation - employees in this type of layout will probably be able to perform a variety of tasks on multiple machines, as opposed to the boredom of performing a repetitive task on an assembly line. A process layout also allows the employer to use some type of individual incentive system. Furthermore, system protection is another advantage. Since there are multiple machines available, process layouts are not particularly vulnerable to equipment failures. However, the major disadvantage includes utilization. Note that the equipment utilization rates in process layout are frequently very low, because machine usage is dependent upon a variety of output requirements. Additionally, constantly changing schedules and routings make juggling process requirements more difficult.

This paper incorporated a simple approach to critical path analysis in a project network with activity times being fuzzy numbers for optimizing a process layout for medium scale industries. Yager's ranking method [2] is adopted to transform the fuzzy CPM problem to a crisp one and the analytical exercises are beyond the scope of this paper. Yager's ranking method also possesses linearity and additivity properties since it is one of ranking techniques based on area compensation. Note that the critical path and total duration time can be obtained from the derived optimal solution [1]. Note that the proposed approach is very simple to apply, and it is not require knowing the explicit form of the membership functions of the fuzzy activity times. Also note that new materials and production technologies demand improved non-destructive techniques for inspection and defect evaluation, especially when critical safety applications are involved. Non-Destructive Testing plays a vital role to achieve reliability and quality at an acceptable cost. Failures of engineering materials, components and structures are well known and can be disastrous. Avoiding the failures cost effectively ensuring safety of use and reliability on a wide range of industrial components are the major industrial NDT objectives. Nowadays, there is a broad range of NDT methods based on different physical principles but the most commonly used are ultra-sonic and eddy currents, X-radiography, magnetic particles and dye penetrant. Therefore, this study leads to say that commissioning suitable intermediate NDT facility to any industry with lucrative process layout will compliment an increase in overall profit.

V. CONCLUDING REMARKS

Experiences gained through this study, and further our industry data base, reveals that the end product rejection rate is on the order of 10 % amounting large profit loss. In order to avoid these rejection rates and to increase the quality product production an intermediate non-destructive testing (INDT) facility has been recommended for selected industries for increasing the overall profit. We observed through the detailed case studies that instead of a centralized facility, commissioning intermediate NDT facility to medium scale industries, the overall production cost can be reduced. This benefit is achieved due to the rejection of the defective products well before its final shape. Additionally, the defective products identified during the intermediate stage can be utilized for other applications or recycling and/or as a raw material for other selected products; thereby the overall wastage of the raw materials can be reduced and profit can be increased. We concluded that the prudent design of a factory layout through critical path method facilitating with INDT facility will warrant profitable outcome to any industry.

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