DESIGN AND COST ANALYSIS OF MOLD MAKING FACILTY AT GHANI GLASS INDUSTRY: A CASE STUDY

Muhammad Ismail[1], Shahid Maqsood[1*], Abdul Shakoor[2], Feroz Shah[2]

ABSTRACT

It is important for the manufacturing and service industry to reduce their costs and expenses to maintain a sustainable position in the global marketplace. Selecting the right manufacturing strategy and planning is a critical decision for production managers in the industry. The layout problems generally exist in the manufacturing industries. In the industries the layout problems deals with the facilities like departments, machines etc. As a case study, this paper presents a machine shop producing molds for local based bottles production industry. The mold making machine shop capacity is enhanced to fulfill the annual requirement by minimizing travel distance, removal of bottlenecks during production, material handling and losses. Firstly, several layouts were generated using Systematic Layout Planning (SLP) method and efficiency rate is calculated. The cost analysis of the modified layout was calculated by giving a payback period also. The results show that the proposed layout performs efficiently for the annual demand.

KEYWORDS: *Cost analysis; Facility layout; Production systems; Systematic layout planning*

INTRODUCTION

The design of facility layout is considered from a strategic perspective because of its direct impact on the overall performance of the system in terms of cost and time. A facility is like a work center, a machine tool, a machine shop or a machine cell that facilitates the execution of manufacturing process of any job (Heragu and Kusiak, 1988). The design of facility layout is basically a planning for geographical positioning of process elements, which are required for services or products production. The process elements, to be positioned, depend upon the operation's sequence of a job/product, which can be an arrangement of machines or work-centers, utilities, location of materials, industrial elements involved in the production system of the factory, the allocation of area and specifying location of different departments (Aiello, Enea *et al.* 2002). Facility layout design is strategic decision made before installation phase requiring capital investment and planning efforts. Giving a little time to obtain a good facility layout before installation may save financial investment and production losses instead of having a poor layout (Benjaafar, Heragu et al. 2002). An efficient placement of facilities adds to the overall efficiency of operations and can minimize the total operating expenses. The objective of the facility is to produce products of high quality at lowest cost with shorter lead times. It is imperative that the layout facilities shall be managed accurately in order to achieve the organization's objective.

In manufacturing sector the placement of facilities has a significant impact upon productivity, work in process, manufacturing costs and lead times. The location decision of facilities placement is generally referred to as "facilities layout planning" is among the most commonly occurring complex problem in the industry (Jia, Xiaohong *et al.,* 2013). The overall efficiency of operations depends directly on the placement of facilities and can minimize the total operating expenses. A facility layout is an arrangement of machines, a work-center, a machine shop, a manufacturing cell, a department, a warehouse, etc. facilitates any job the execution (Djassemi, 2007). The facility layout design flourishes the decisions of process configurations. It involves selection on technology alternatives for process elements such as machines layouts and their limitations. Mostly in manufacturing systems, the decision of process configuration determines the type and quantity of resources and their capabilities. It also determines installation constraints of machines from one another (Kulturel-Konak, 2007). Once process configuration are determined, facility planner's aim is to arrange resources as per design criteria. In facility layout problems, in literature the minimization of material handling distance/cost is commonly used (Amaral, 2006). The facilities design main component, material handling process involves movement of raw material, work-in-process inventoryflows between workstations and respective storage locations (Muthiah and Huang, 2006). The transportation activities through manned/unmanned material handling equipment such as forklifts, automatic

*1 *Department of Industrial Engineering, University of Engineering & Technology Peshawar.*
2 Department of Mechanical Engineering, University of Engineering & Technology Peshawar.

guided vehicles, conveyor belts, assembly lines, etc are managed as per production schedules (Gu, Goetschalckx *et al.,* 2010). In facility layout design, the minimization of the total material handling cost has a direct relation with the total distance traveled by the material handling equipments. There are two different facility shapes regular (generally rectangular) and irregular(generally polygons) are notable (Hong, Seo *et al.,* 2014). According to the products variety and production volumes the layout design is further categorized into four types namely product layout, process layout, combination of process and product layout and cellular layout (Ucar and Bayrak, 2015). The facility layout problem can be distinguished on the base material handling such as single row facility layout, multi row facility layout, open-field layout and loop layout (Yang and Kuo, 2003). In single row layout the facilities are organized in a straight line. The multi rows layout consist of several rows of facilities and the movement of parts take place between the same rows and different rows. In the loop layout the parts enters and leaves the layouts in a loop with a common load/ unload station. The open field layout deals with the situations in which facilities can be placed without the limitations or constraints that would be considered by such arrangements as single row or loop layout (Yang, Peters *et al.,* 2005). Bypassing and backtracking are two particular movements that occur commonly in flow-line layouts, which affect the flow of the products. Bypassing take place when a part skips some facilities during its flow line arrangement when moving a part from one facility to another facility (Chen, Wang *et al.,* 2001). Backtracking occurs when a part moves from one facility to another preceding it in operation sequence of facilities in the process flow-line. Production Line Formation Problem (PLFP) considers the number of these movements, which determines the orders (total or partial) of machines such as to minimize the sum of arrows whose direction is opposite to the global flow of products, whereas considering constraints on the rank of machines (Chen* and Sha, 2005). It is important to determine the position from which parts enter and leave facilities, called Pick-up and Drop-off (P/ D) points, while they can be potentially placed at various locations (Kim and Kim, 2000). For layout problems the Quadratic Assignment Problem (QAP) model has been used, which models the location of interacting plants of equal areas. The QAP has been used widely in various applications with the assumptions that all units have equal areas and locations are fixed with a known priority (Moslemipour, Lee *et al.,* 2012). The computer based Construction algorithms like ALDEP (Automated Layout Design Program) and CORELAP (Computerized Relationship Layout Planning) are also used to produce the layout without having any initial layout. Improvement algorithms, like CRAFT (Computerized Relative Allocation of Facilities) and COFAD (Computerized Facilities Design), starts with an initial layout and try to improve it (Azadeh and Moradi, 2014). According to the increase of competition in the manufacturing sector, survival has become difficult. Manufacturers try to deliver high quality products at low cost for their sustainability. To know about the price of a product is to study the costs and losses involved in that process. There are many factors that affect the cost. One of the important factors on which the overall cost depends is the facilities placement in an industry. It means that poor facility layout increases the cost (Lee and Lee, 2011). For this purpose companies try to select an effective layout for their facilities to have uninterrupted production flows. By achieving a proper layout at the time of installation will result a lot of saving in capital investment and production lost. On the other hand poor layout needs rearrangement frequently which wastes time and investment. The manufacturers also want to produce products and enhance their production capacity to compete in the market place. The objective of the facility is to produce products of high quality at lowest cost with shorter lead times. It is imperative that the layout facilities must be managed accurately to achieve the organization objective (Mohsen and Hassan, 2007). There may be internal or external factors for the modification of a layout or creating a new layout. External factors are effects from the environment or outside the plant layout. These factors are either tough or impossible to alter. Internal factors, on the other hand, results from design inefficiencies and have nothing to do with the external factors. The internal factors are basically the need for modification that arises due to the changes in demand, products or processes or most likely from combination from those three (Xing, Li *et al.,* 2016). The facility planning development is categorized as comprising construction and improvement. In the construction methods a sustainable layout is developed from the beginning and in improvement ones a number of alternatives are generated for the existing layout. Muther et al. (Chien, 2004) proposed a method for layout designing that giving a little time for arrangement of facilities before installation minimizes losses considerably known as Systematic Layout Planning (SLP) method. It is powerful approach and is used to develop the overall shop floor layout. To find the optimal layout data input, procedure's process, output results and evaluation process are required (Wiyaratn, Watanapa *et al.,* 2013).

Glass industry is divided into two main sectors i.e. containers glass and float glass. The containers glass is produced on the principle of blow molding. In blow molding process for the production of glass bottles molds are used. For the manufacturing of molds almost in every glass industry there is a dedicated mold making machine shop which manufactures molds or outsources according to their annual requirement. Here in this study the mold making machine shop of a local glass industry is studied where the annual demand is more than annual production of molds, hence they purchase molds from other companies at a higher cost. The main objective of this study is to modify an existing mold making machine shop layout to fulfill their annual production demand and also to develop cost analysis of the modified facility. The subject matter of this research work is layout designing and cost analysis which is not presented anywhere in a combined way. Moreover the layout designs are made in general and not specific to machine shop. Similarly the cost analysis is there but their financial models and their financial impacts are not present. The systematic layout planning method is used for the development of layout and cost analysis is done for the modified setup.

The remainder of the article is organized as follows. In Section 2, methodology is presented consisting of layout designing and cost analysis of the proposed layout. Section 3 is detailed for discussion of the results and Section 4 describes conclusion and suggested areas for further research.

MATERIAL AND METHODS

In the introduction section the problem is explained. An overview of the process flow is shown in Figure 1. It shows that the machining processes is carried out during mold manufacturing. The mold manufacturing process starts with the machining of two half-cylinder blocks on Shaper machine for surface grinding. On completion of surface grinding operation the two half molds (male and female parts) are sent to lathe machine for lathe operation. After turning operation the fitter starts facing operation by using gland emery to remove uneven points on the mold surface. On Copy lathe machine internal machining operation is performed for rough cut. After this operation the molds are passed to milling machine for cutting groves for filling welding process. By grinding operation the extra welding is removed. The molds are processed for half part checking to see both the parts are equal. When this process is complete the mold is passed for final gauge where finish turning operation is performed followed by final internal turning on Copy lathe machine. For keys and side cutting it is again passed to Shaper machine where these operations are performed. Some drilling operations of 0.7mm are performed on mold for the purpose to make a way for the entrap gases in the mold during the blow molding process. When all the machining processes are complete the final inspection process is made where these molds are checked against various dimensions and the quality passed molds are stored in warehouse.

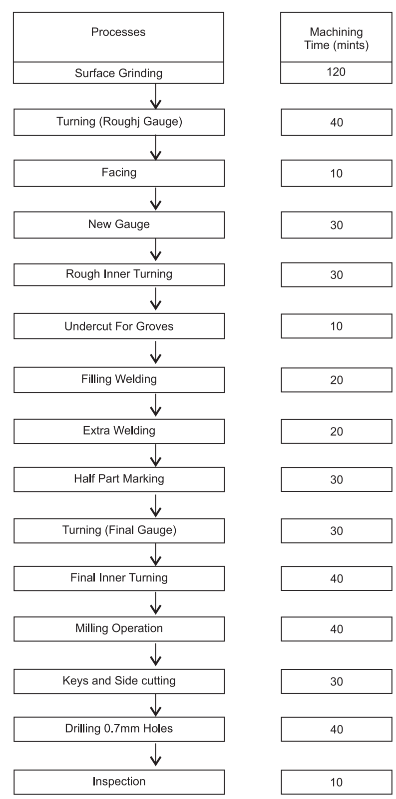

Figure 1: Process flow chart.

The machines are placed without having a proper layout in the existing setup which results problems in placement of new machines. The existing mold manufacturing machine shop layout is shown in Figure 2. The locations of the machines are not in sequence with the process flow due which mold travels more distance and takes more time than the required. The existing machine shop is running under low capacity, hence does not fulfill its annual demand.

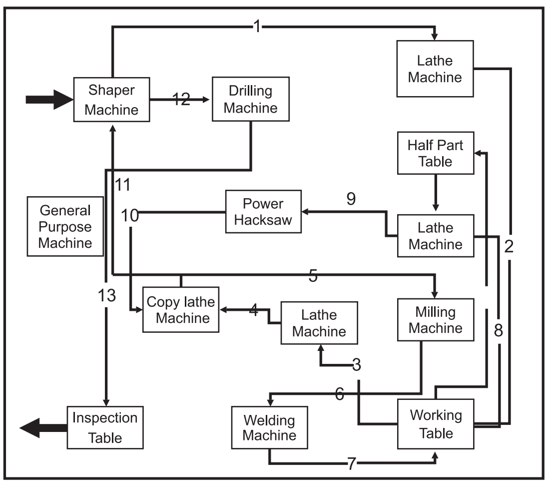

Figure 2: Schematic of existing layout.

Table 1 shows the Annual molds requirement. In Table 1 there are three columns and eight rows. The first column shows the years followed by total molds required annually in the second column. The third column is related to molds share which is further divided into in-house molds production and molds outsourcing. For example in year 2010 a total of 1920 molds were required in which 1390 molds are produced inside the plant and the remaining molds are purchased from other manufactures.

Table 1: Annual molds requirement.

Year	Total Molds required annually	Molds share		
		In-house	Molds Outsourced	
			Local	Import
2010	1920	1390	330	200
2011	1900	1398	352	150
2012	2000	1400	400	200
2013	2150	1398	502	250
2014	2200	1413	487	300
2015	2300	1415	585	300

This data is also shown in Figure 3. From this graphical presentation it is clear that the plant molds production capacity is almost constant while the purchase of molds from outside sources is increased constantly. The in-house production capacity is nearly 1400 units from years 2010 to 2015 which is almost constant while the demand from local and import sources is increasing constantly.

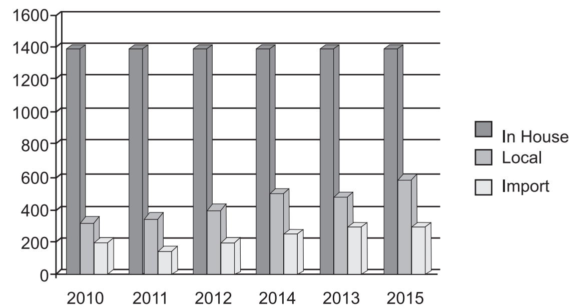

Figure 3: Annual requirements of molds.

The study of process flow shows that there are two bottlenecks. To remove the bottlenecks two machines are added. For machines placement Systematic Layout Planning method (SLP) is used to modify the layout.

Systematic Layout Planning (SLP)

By using SLP technique, activity relationship chart is developed according to the process flow and interrelationship between machines. The intersection of two workstations boundaries shows a letter identifying the importance of their proximity. The activity relationship chart is shown in Figure 4.

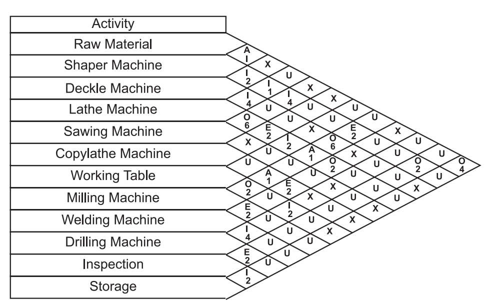

Figure 4: Activity relationship chart.

The proximity ratings are shown in Table 2. The A,E,I,O,U and X values in the activity relationship chart are given according to closeness in process flow. The

Table 2: Proximity rating.

VALUE	CLOSENESS
A	Absolutely Necessary
E	Especially Important
I	Important
O	Ordinary Closeness
U	Un necessary
X	Not Desirable

Table 3: Reason codes.

Reasons	Codes
Flow of Material (Process Sequence)	1
Economy of Transport	2
Production Control	3
Ease of Supervision	4
Same Workers	5
Convenience	6

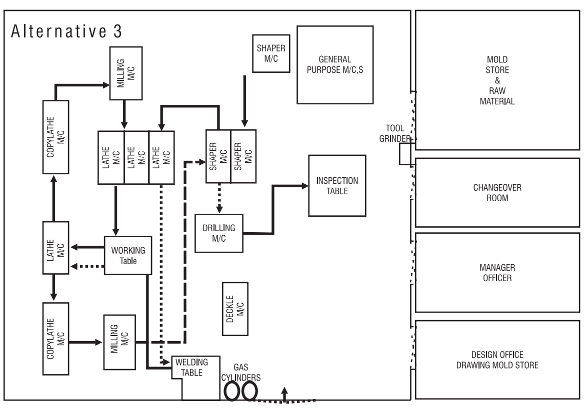

Fig 5: Modified layout.

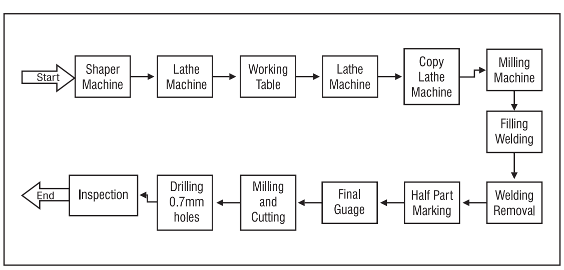

Figure 6: Process flow diagram.

reason codes given in Table 3. describes that how the proximity is developed.

In Figure 5, the modified layout is presented. In the modified layout all the machines are placed according to the operation sequence with the aim of overcoming bottlenecks and reduction in the total distance travelled with a shorter lead time which is shown in results section.

The part enters the Shaper machine for surface grinding operation and follows the operation sequence shown in Figure 6.

Cost Analysis

The cost analysis covers the total cost of the modified facility of mold making workshop and give a full detail of the material, equipment and machinery, labor and running costs. But before going to find the total cost it is very necessary to have a clear quantity of the total annual demand, the total operating time per day and per year and number of days for which plant is in operation in a year.

Total parts produced per year are given as V_{gross}, the gross number of molds produced with an overall annual demand, net volume, V_{net} and the reject rate, rej, which is considered 2.5 % in this case. The reject rate is included because during manufacturing some of the parts produced are not according to desired specifications and dimensions and hence rejected.

$$V_{gross} = V_{net} / 1\text{-rej} \qquad (1)$$

From Table 1, putting the value of outsourced molds of year 2015 in equation 1, the V_{gross} comes out to be 907 molds.

Financial Model And Calculation Of Cost

The financial model is developed by applying factor prices to the resource requirements explained above. The total costs included in the model are divided into three categories:

$$C_{total} = C_{material} + C_{labour} + C_{expenses} \qquad (2)$$

The cost of materials will cover all the materials that take part directly or indirectly in the manufacturing process are going to be computed. Direct Material is composed of the materials that are a major part of the final product. These materials must be properly noted and assigned to cost units.

The p in the equation (3) indicates the price of the unit mold and P_{scrap} represents the price of the rejected parts which are 2.5 % of the V_{gross}.

$$C_{material} = pV_{gross} - (V_{gross} - V_{net})p_{scrap} \quad (3)$$

V_{gross}=907 molds , p=Rs.5100/_

p_{scrap}=Rs.1000/_, V_{net}=885 molds

$C_{material}$=Rs.4.62 millions/_

The equation (4) characterizes the human contribution to production and it is almost the second most main group in the product costs. Hence, this group is often kept on top priority. Labor cost is the product of the paid time required to produce the target volume, and the labour wage rate p_{wage} .

$$C_{labour} = APT \times p_{wage} \times NL \quad (4)$$

APT is the annual paid time which in this case is 12 months, shows the average salary of the employee and NL shows the number of employees involved in the process.

APT = 12 months/year, p_{wage}= *Rs.18000/month*

and Number of workers (NL) = 12

C_{labour}=Rs.2.5 millions

All the costs invested by the industry or organization that does not come in material or labor costs are termed as expenses. Overall it is the third group and it is important for the cost calculation because it consist of overhead, the utilities, and the initial investment in construction of building & purchase of land, procurement of machines and the tooling cost respectively.

$$C_{expenses} = C_{overhead} + C_{energy} + C_{building} + C_{equipment} + C_{tooling} \quad (5)$$

$C_{expenses}$=Rs.7.98 millions

By putting all values of cost in equation (1) we get the total cost. In total cost all the costs are running costs except the capital investment.

$$C_{total} = C_{material} + C_{labour} + C_{expenses}$$

C_{total}=Rs.15.2 millions

This Rs.15.2 million is the total cost will come in the first financial year.

RESULTS AND DISCUSSION

In total, the use of SLP method has resulted in three layouts alternatives involving twelve machines. Selecting the best layout covers the first part of this study. In all these three alternatives the machines relating to each of the process have been occupied in a small area with the correct and best implementation of operation sequence. In the Table 4, a comparison is established between the existing layout and the alternatives developed according to total distance, total time and the production per day. The layout having minimum distance travelled, shorter lead time and maximum production rate is selected.

After having the best alternative selection, the next step is to find cost effectiveness of the modified layout. The cost saving is shown in Table 5. From table it is clear that a total of Rs.3.62 million can be saved if all the molds are manufactured inside the plant.

Table 4: Comparative analysis w.r.t distance, time and production rate

No.s	Total Distance (ft)	Total Time (minutes)	Production Rate (parts)
Existing Layout	620	1020	5 Parts
Alternative-1	530	1040	8 Parts
Alternative-2	550	1100	8 Parts
Alternative-3	480	940	8 Parts

Internal Rate of Return and Payback Period Analysis

The investment incurred in purchase of equipment and building is justified by internal rate of return method and payback period analysis. The cost analysis describes two types of costs i.e. capital cost made in purchase of machines, space, building and the other cost is the running cost which is made every year.

The Internal Rate of Return(IRR) is a trial and error method which is calculated according to the following

Table 5: Cost saving.

Mold Sources	Cost Per Mold	Cost Saving per mold A	Molds Produced B	Annual Saving a*b
InHouse	Rs.10952/-	Nill	907	Rs.0
Local	Rs.16000/-	5048	600	Rs.3 million
Import	Rs.13000/-	2048	307	Rs.0.62million

equation:

$$0 = \sum_{t=1}^{T} C_t / \left(1+r\right)^t - C_o \qquad (6)$$

Where C_o represents the total initial capital investment, C_t represents the net cash inflow during the period T, r is the discount or return rate and t is the number of years.

The useful life is five years and the investment incurred generates profit of Rs.3.66 million in the 1st year, Rs.2.92 million in the 2nd year, Rs.2.74 million in the 3rd and 4th and Rs.2.5 million in the 5th year.

$$0 = (-5.27 + 3.66/1.45 + 2.92/1.45^2 + 2.74/1.45^3 +$$

$$2.74/1.45^4 + 2.5/1.45^5) \text{ million}$$

$$0 = 0.012$$

which is almost equal to zero. As 45% is greater than the interest rate paid by bank which is 6%, hence the investment in project is beneficial.

For payback period analysis only the capital investment is encountered. The capital investment is Rs.5.28 million and the annual saving is Rs.3.62 million which results in a payback period of 15 months.

CONCLUSION AND FUTURE WORK

In this study an existing layout for a mold manufacturing machine shop is modified regarding the need to enhance the molds producing capacity using facility planning and design strategies. The first step is to develop such a layout that increase the production with the objective of minimizing the distances travelled and the respective lead times. In the second part the cost analysis of the modified facility was carried out by considering all the elements involved in the manufacturing process. SLP is a constructive type technique adopted for facility planning. As a whole three alternative layouts were developed in this thesis using SLP method. The layout selection was made by measuring the distance covered in manufacturing process and minimizing the bottlenecks in the production lines by incorporating new machines into the system. The bottlenecks in the production flow lines identify the number of machines required to increase the output. As new machines were added to overcome bottlenecks the cost also increases. To justify cost to manufacture all the parts without outsourcing was done by comparing the costs incurred in manufacturing a single set in-house with the local and import molds.

The potential areas for future research include application of methods like Graph Based Theory (GBT) and other constructive techniques to modify a layout and compare their results. The simulation techniques may be applied to improve the results. Based on this study it is concluded that this research work may get broaden to cover all the departments of industry and the interrelationship between them.

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