A Proposed Study on Facility Planning and Design in Manufacturing Process

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Abstract— Facility planning is concerned with the design, layout, and accommodation of people, machines and activities of a system or enterprise within a physical spatial environment. Facility planning is very important in a manufacturing process due to their effect in achieving an efficient product flow. It is estimated that between 20%-50% of the total costs in manufacturing is related to material handling. This cost can be reduced until 30% through an effective facility planning. Proper analysis of facility layout design could improve the performance of production line such as decrease bottleneck rate, minimize material handling cost, reduces idle time, raise the efficiency and utilization of labour, equipment and space. Many researches have been done in finding optimum facility design. Heuristic methods for layout optimization are Tabu Search (TS), Simulated Annealing (SA), and Genetic Algorithms (GA). Beside the heuristic methods, simulation technique is also recommended in optimizing of facility design. This paper discusses on previous study and significant finding in facility planning and design. A research direction on facility layout design using combination of methods has been proposed.

Keywords-- Facility planning, layout optimization, simulation

I. INTRODUCTION

Future manufacturing system needs to be dynamically reconfigurable to produce customized products in small batch with fast turn-around times in cost-efficient manner [17]. The capability to reconfigure an existing manufacturing system is a key factor to maintain competitiveness in manufacturing business environment [5]. Taha *et al* [22] suggested that in order to be successful in today's competitive manufacturing environment, managers have to look for new approaches to facilities planning.

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According to Balakrishnan *et al* [5], it was estimated that over $250 billion is spent annually in the United States on facilities planning and re-planning. Further, between 20%- 50% of the total costs within manufacturing are related to material handling and effective facility planning can reduce these costs 10-30%. Many researches have been done in facility planning area. However, there are some difficulties and limitation in finding the optimum layout configuration.

II. FACILITY PLANNING

Facility planning is concerned with the design, layout, and accommodation of people, machines and activities of a system or enterprise within a physical spatial environment [8]. Furthermore, Huang [13] states that facility layout design determines how to arrange, locate, and distribute the equipment and support services in a manufacturing facility to achieve minimization of overall production time, maximization of operational and arrangement flexibility, maximization of turnover of work-in process (WIP) and maximization of factory output in conformance with production schedules.

In manufacturing systems, the three main types of layout are product layout, process layout, and group layout, which is further categorized into flow line, cell, and centre [3]. According to Tompkins [23], the distinction between these types of layout is made based on system characteristics such as production volume and product variety. Hessen [11] stated that product layout (flow shop) is associated with high volume production and low product variety, while process layout (job shop) is associated with low-volume production and high product variety (Fig. 1).

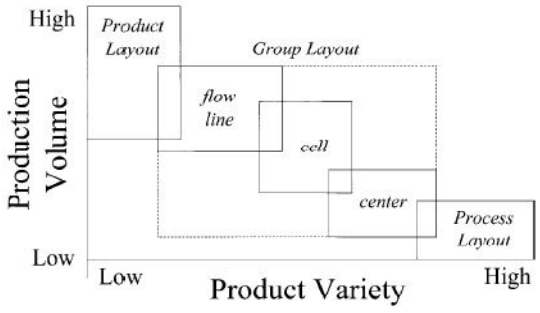

Fig 1.Types of layout

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In today's competitive market, manufacturing industries have to satisfy more diverse queries from the market, such as widening the product ranges, increasing quality and precise the delivery time [18]. The international competition also requires a larger variety of types and variants in large volume product. Zuhdi *et al* [25] suggests that manufacturing companies need to be knowledge-intensive and highly creative to develop new products. To remain competitive, upgrading the process and adopting information technology are also the challenge of small and medium industries. Decision making for either upgrading the specific process or reconfiguring the whole system as a response to market demand is a critical activity which can impact on the economical aspect of the company. Hence, it must be supported by an appropriate analysis tool. According to Rieth, *et al* [20], the simulation method is preferred because of the capability in capturing the dynamics of the complex system. The important of simulation in the era of lean manufacturing is the validation of the design or redesign of a complex manufacturing system before implementation.

III. TOOLS FOR OPTIMIZING LAYOUT DESIGN : HEURISTIC METHODS

The most well known heuristic methods in optimizing layout design are Tabu Search (TS), Simulated Annealing (SA), and Genetic Algorithms (GA). The popularity of these heuristics has flourished in recent years and several published studies can be found in the literature. Arostegui, *et al* [2] classify heuristics methods into tailored and general. While tailored heuristics have a limited applicability to a specific problem, general algorithms define a strategy for obtaining approximate solutions and thus are widely applicable to various forms of combinatorial optimization problems.

Tabu Search (TS) is a mathematical optimization method, belonging to the class of local search techniques [2]. Tabu search enhances the performance of a local search method by using memory structures, once a potential solution has been determined, it is marked as taboo, so that the algorithm does not visit that possibility repeatedly.

A genetic algorithm (GA) is a search technique used in computing to find exact or approximate solutions to optimization and search problems [2]. Genetic algorithms are categorized as global search heuristics. Genetic algorithms are a particular class of evolutionary algorithms (EA) that use techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover [4].

Simulated annealing (SA) is a generic probabilistic metaheuristic for the global optimization problem of applied mathematics, namely locating a good approximation to the global minimum of a given function in a large search space [2]. It is often used when the search space is discrete. For certain problems, simulated annealing may be more effective than exhaustive enumeration, provided that the goal is merely to find an acceptably good solution in a fixed amount of time, rather than the best possible solution [4].

IV. SIMULATION TECHNIQUE

Simulation technique is also recommended in the facility planning analysis. Nica, *et al* [18] reported that queuing phenomena of parts before entering assembly area is in uncertainty arrival time. Simulation is an appropriate tool to help the designer to define the storage spaces of assembly system in this stochastic situation. In this research, a concept of ordered parts buffer is proposed for sequencing parts arrived in the assembly process by robot systems. Simulation based on experimental design is developed by Ekren and Ornek [6] for typical manufacturing job-shop system. They investigated the effects of layout types and their interactions with other manufacturing parameters that can affect performance of the system.

A simulation model has been developed as an analysis tool for line reconfiguration to accommodate the future demand fluctuation. Line balancing becomes the main issue in the research and fuzzy knowledge base of technique was proposed to help define more realistic scenarios [20]. The necessity of sequence coordination within a complex assembly system is reported. This is due to the fact that the complex assembly system generally includes preassembly section for part preparation and this can only be determined by computer-aided simulation.

Simulation tools that commonly used in facility planning are Arena [9], QUEST [17], IGRIP [17], ProModel [25] and Witness [21]. Another tool that can be used in layout simulation is Flexsim software. Flexsim is discrete event simulation software, used for evaluating, planning or designing manufacturing, warehousing, logistics and other operational and strategic situations [7]. The limitation of many softwares is they only provide the two dimensional visualization (2D), which is not easy to visualise, understand and evaluate. Flexsim is provide the three dimensional (3D) visualization. The use of Flexsim software can be described as follows. Facility is defined as a collection of resources that are intended to function together in a cost-effective manner. The resources are including the machine, material, and manpower. Each manpower and piece of equipment is related to every other component, by coincidence or convenience. Together they define the way of facility's works. Flexsim software will help to arrange all of part of the factory and reconfigure the pieces to find ways in making the entire system run efficiently. Flexsim software will help researchers to test multiple alternatives in a short time without any risk, disruption and expenses.

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V. RECENT STUDY ON FACILITY PLANNING

Table 1. Research Comparison

No	Title and Author	Methodology	Finding
1	An Empirical Comparison of Tabu Search, Simulated Annealing, and Genetic Algorithms for Facilities Location Problems. (Arostegui *et al*, 2006)	Compare the relative performance of Tabu Search (TS), Simulated Annealing (SA), and Genetic Algorithms (GA) on various Facilities Location Problems (FLP).	The results indicate that TS shows very good performance in most cases. The performance of SA and GA are more partial to problem type and the criterion used. Thus, in general it may conclude that TS should be tried first to the extent that it always yields as good or better results and is easy to develop and implement.
2	Genetic Algorithms for Integrating Cell Formation with Machine Layout and Scheduling. (Xiaodan *et al*, 2007)	Propose a new approach to concurrently make the cell formation (CF), group layout (GL) and group scheduling (GS) decisions for a successful Cellular manufacturing (CM). A conceptual framework and mathematical model, which integrates these decisions, are proposed. A hierarchical genetic algorithm (HGA) is developed to solve the integrated cell design problem. Two heuristic operators are proposed to enhance its computational performance.	The result of this study indicate that: (1) The concurrent approach often found better solutions than the sequential one. (2) With the proposed heuristic operators, the hierarchical genetic algorithm (HGA) procedure performed better than without them.
3	Using Simulation for Facility Design: A Case Study (Greasley, 2008)	A discrete event simulation model was developed and used to estimate the storage area required for a proposed overseas textile manufacturing facility. In this study the author acted in a consultancy role and undertook both the process of the simulation study and the construction of the simulation model itself. Tools : Arena Software	It was found that the simulation was able to achieve this because of its ability to both store attribute values and to show queuing levels at an individual product level. It was also found that the process of undertaking the simulation project initiated useful discussions regarding the operation of the facility. Discrete event simulation is shown to be much more than an exercise in quantitative analysis of results and an important task of the simulation project manager is to initiate a debate among decision makers regarding the assumptions of how the system operates.
4	A Study on Facility Planning in Manufacturing Process Using Witness. (Roslin *et al*, 2008)	Comparing two alternative design of layout : U-shape and S-shape. The study is conducted in Dinamika Pelumas Sdn. Bhd. Simulation tool using Witness software.	This paper found that U-shape flow pattern design has increase the efficiency utilization of labour, equipment, space and reduces idle time.
5	Metaheuristic methods for a class of the facility layout problem. (Alvarenga *et al*, 2000)	Comparation of simulated annealing (SA) and Tabu Search (TS).	Both methods produced the known optimal solution for a facility layout problem set with high frequency and low computation time.
6	Solving the failure-to-fit problem for plant layout by changing department shapes and sizes. (Lin *et al*, 1996)	Apply Artificial intelligence (AI) to FLP	Artificial intelligence could solve the scenario of failure-to- fit solutions, when no feasible layouts are generated.
7	Virtual Reality Simulation of Mechanical Assembly Production Line. (Kibira et al, 2002)	Modeling the production line operation presenting workstation and material handling system. Simulation tool used are QUEST and IGRIP software.	This paper demonstrated a method of designing a manufacturing process from a prototype of the product using virtual reality simulation.

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Table 1. Research Comparison (continue)

No	Title and Author	Methodology	Finding
8	Simulation Model for Production Line Layout. (Zuhdy *et al*,2008)	Existing layout is evaluated by Using Promodel software by Integrating Process layout, constant period scheduling and Short processing time.	This paper proved that the simulation model is capable to predict the capacity of initial system and test the proposed design.
9	Design and Analysis of a Virtual Factory Layout. (Iqbal and Hashmi, 2001)	All production machines created in AutoCAD and imported to 3D Studio Max software. Layout problem was visualized and modified by applying Facility Layout Problem (FLP) solving techniques.	Virtual factory layout helps in evaluating plant layout before actually building them and assists in avoiding the cost involved in doing physical re-layout. By virtual factory layout, a designer can have feel of the actual setting of the factory, easy to visualize, understand and evaluate. Re-location of the machine can be done such that the material handling cost reduced as well as the bottleneck removed.
10	Layout Design in Group Technology Manufacturing (Hassan, 1994)	Literature review	A review and consolidation of the emerging literature in the GT layout and a suggestion framework of analysis for developing the GT layout.
11	Advances in Discrete Material Handling System Design. (Rajagopalan and Heragu, 1997)	Literature review	This paper presents an outline of trends seen in layout and material handling flow path design research. The current trends are to integrate the different aspects of the manufacturing system design problem. Also present an idea for solving P/D (Pick-up/Drop off) point location and material handling flowpath problem.
12	A Classification of Different Type of Facility Layout Design. (Taha *et al*, 2008)	Literature review	This paper discusses on the objectives of facility layout design, flow pattern and material handling systems and finally discusses the different type of layout.
13	Multiple objective facility layout: a heuristic to generate efficient alternatives. (Malakooti, 1989)	Using Heuristic and metaheuristic methods to solve FLP.	Both methods find sub optimal or near optimal solution have been successful on some problems but not on a universal level. However, it is depend on decision assumption made by problem solver and the time required to compute solution is lengthy.
14	Comparison of solution Procedure to the Facility Layout Problem. (Houshyar and White, 1997)	Comparing Binary NP-complete and Integer Programming (BIP) methods	The BIP was able to find near optimal layout quickly for highly specialized problems with sixteen departments or less.
15	FACOPT : A user friendly Facility Layout optimization System. (Balakhrishnan *et al*, 2003)	Comparation of genetic algorithm (GA) and simulated annealing (SA).	The genetic algorithm model performed better than the simulated annealing model in terms of time required to compute solution.

A comparison study of relative performance of Tabu Search (TS), Simulated Annealing (SA), and Genetic Algorithms (GA) on various Facilities Location Problems (FLP) are done by Arostegui *et al* [2], Alvarenga *et al* [1], and Balakhrishnan *et al* [4]. In general, TS shows very good performance in most cases. The performance of SA and GA are more partial to problem type and the criterion used. Thus, in general it may conclude that TS should be tried first to the extent that it always yields as good or better results and is easy to develop and implement.

Genetic Algorithms (GA) can be an effective approach for solving facility planning problem such as complicated integrated cell design. According to Xiaodan, *et al* [24], their experience of using GA indicated that it is critical to consider heuristics in the proper stage of implementation, and it takes longer for GA to perform its computation than conventional heuristics. In this study, they proposed a heuristic mutation method to speed up the convergence process. However, they need to conduct more pilot tests to find out where is the proper place heuristic knowledge can come into playing in the most effective manner. This remains a critical issue for further study.

A study in improvement of existing layout design of a manufacturing process has been done by Roslin *et al* [21]. The new proposed layout design for manufacturing production line in this study is the product

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layout type where the arrangement of activities in a line is standardized according to the sequence of operations and production tasks. The methodology used is comparing two alternative design of layout: U-shape and S-shape. In this study the Witness simulation software, is used to determine the line efficiency of the designed layout plant. The simulation is done based on the new layout design to illustrate the efficiency of the line and to get an initial idea if the layout plant is eventually picked to be implemented by the company. In the first proposed design, the flow pattern used is a combination of Straight line and U-shaped. The U- shaped of flow pattern is use in the first half of the process and the Straight line flow pattern is use in the second half of the process. In the second design, the flow pattern used is S-shaped. The result of the study done by Roslin *et al* [21] shows that U-shape flow pattern design has increase the efficiency utilization of labour, equipment, space and reduces idle time.

Another study about layout design was done by Mc Lean and Kibira [17]. But it was focussed in the assembly system as a part of manufacturing system. The objective in this study was analysed assembly operation into different tasks and allocation of these tasks to different assembly workstations. The methodology used is a graphical modelling & discrete event simulation of overall process flow. Simulation tool QUEST & IGRIP software was used to build a model for mechanical assembly production Line. The result is a method of designing a manufacturing process from a prototype of the product using virtual reality simulation.

Study about a development of existing layout also done by Zuhdi *et al* [25]. The existing and proposed configuration of new layout is evaluated by integrating process layout, constant period scheduling using short processing time and batch sizing into the simulation model. The result obtained from the simulation study proved that it is a powerful tool to evaluate the proposed layout design before the actual implementation.

A Simulation study to support layout design analysis has done by Iqbal and Hashmi [14]. But this study focused on the design and analysis of a virtual factory layout. Virtual factory layout helps in evaluating plant layout before actually building them and assists in avoiding the cost involved in doing physical re-layout. Re-location of the machine can be done such that the material handling cost reduced as well as the bottleneck removed. By this virtual factory layout, a designer can have feel of the actual setting of the factory, easy to visualize, understand and evaluate.

VI. DISCUSSION

Based on the review of some literature, there are several studies investigated the effective design of facility planning in a production line of manufacturing process. However, there are some difficulties and limitations in finding the optimum layout configuration with general heuristic methods such as Tabu Search (TS), Simulated Annealing (SA), and Genetic Algorithms (GA). The limitations are such as time consuming and cannot get the feel of the actual setting and actual dimension of the machine and equipment in the facility design.

Simulation technique is a powerful tool to asses and evaluates the possible configuration in layout optimization. According to Mc Lean and Kibira [17], simulation could be the best aid in decision making during design, analyse and improvement of manufacturing systems and computer simulation also shows great promise for raising productivity, improving product quality, shortening lead time and reducing cost in the future.

Some researchers used Arena, Witness, and Promodel, which are (2D) simulation software. However, 2D view layout could not provide actual setting and actual dimension of the machine and equipment. In recent years, the development of discrete event simulation softwares grows rapidly. One of them is Flexsim software. It provides three dimensional (3D) view of the layout. This software allows designer to build virtual reality (VR) environment and can have feel of the actual setting of the factory. Potential problems such as safety issues, aisle and other layout problems can be visualized and modified by applying plant layout problem solving techniques.

In the future research of some literatures, there are some new approaches of facility design analysis. One of them is combining the basic heuristic methods with 3D simulation technique in evaluating the existing layout arrangement. The objective is to create more comprehensive analysis to find the optimum layout arrangement.

VII. CONCLUSION

In conclusion, it is found that analysis of facility design such as layout and material handling system is very important in a manufacturing industry. Proper analysis of existing layout design could improve the performance of production line. It could decrease bottleneck rate, minimize material handling cost, reduces idle time, raise the efficiency and utilization of labour, equipment and space. Heuristic methods such as Tabu Search (TS), Simulated Annealing (SA), and Genetic Algorithms (GA) are common tools in optimization. Limitations of those heuristic methods are time consuming and cannot get the feel of the actual setting and actual dimension of the machine and equipment. Beside the heuristic methods, simulation technique is a powerful tool that used by many researchers in creating and evaluating the proposed layout design before implementation. Simulation tools that commonly used in facility planning are Arena [9], QUEST [17], IGRIP [17], ProModel [25] and Witness [21].

The proposed research that will be conducted by author is evaluating existing layout arrangement using combination of heuristic methods and simulation technique. Basic heuristic analysis technique will be used to find a new proper layout configuration. Then, simulation technique by using Flexsim software will be used to evaluate overall performance. Based on literature review, there is no research in facility planning that employs Flexsim simulation software. This combination of techniques is expected to create more comprehensive analysis to find the optimum configuration of the existing layout design in manufacturing process.

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