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Plant Layout Design: A Review Survey

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Abstract:

Plant layout design is related to the location of facilities (e.g. machines, departments) in a plant. They are known to greatly impact the system performance. Numerous research works related to facility layout have been published. A few literature reviews exist, but they are not recent or are restricted to certain specific aspects of these layout design. The literature analysis given here is recent and not restricted to specific considerations about layout design.

We suggest a general framework to design plant layout and present existing works using such criteria as: the manufacturing system features, Preliminaries of Layout Planning, defining layout problem, workshop characteristics impacting the layout and methods, techniques and software available for designing plant layout.

1.Introduction

Plant layout design is the arrangement of departments and equipment in a plant to efficiently produce a product^[6]. Although a company should always consider facility layout to be top priority when the company first starts its business or when it is moving to a new location, a new facility layout may sometimes be needed when a company decides to purchase new machinery or to develop a new product. A poorly designed layout could result in bottlenecks, increased overall production time per unit, increased transportation costs, increased number of accidents, decreased inventory space, etc. Major improvements in facility design took place when this philosophy arrived in Japan. The Japanese developed a management philosophy of continuous improvement based on employee suggestions (Santos, 2006). They developed a term called kaizen that combined continuous improvement with quality circles. This method helped improve communication and used methodologies such as reengineering and major product redesigning. The result of continuous improvement is an improved efficiency in the production, and a reduction in the need for major changes in the long run. The main criteria of having a good facility layout is to ensure the flow of materials, product and communication is efficient. This report will demonstrate some methods and technique available for designing optimize plant layout.

In modern days, the initial planning of a facility layout requires substantial investments. It involves long term commitment into planning the types of products to produce, the number of departments, the constraints of the company size and the possibility of future expansion. The decisions made during the planning could make a large impact on the operations. An optimized facility layout not only improves production efficiency, but it also provides a safer environment for the workers. For example, a shortened walking time between departments could reduce accidents, allow easier communication and even allow forklifts to travel less. Moreover, a better layout could help the company comply to changes in environmental and legal regulations. For example, realigning the production streamline could reduce the need of production transfer across departments and reduce the emission of CO₂^[1]. Also,^[2] different types of productions would have different types of layouts. In general, there are three different types of layouts: process layout, product layout and fixed position layout. These layouts all have their advantages and disadvantages. This report discusses how facilities decide on which layout to use and also analyzes other integrated layouts. As mentioned before, planning a layout is a long term process. However, improved software technology has allowed companies to forecast outcomes of various possibilities and shorten the planning process. These software models allow users to simulate real time scenarios to better see the effect of the layout. More about the software will be looked into throughout this research paper.

2.Literature Review

Anucha Watanapa^[1], proposed an improve the plant layout of pulley's factory to eliminate obstructions in material flow and thus obtain maximum productivity. The present plant layout and the operation process of each section have been investigated. The problem in term of material flow of each operation section was indentified. The result showed that disassembly surface finishing and inspection sections should be allocated to make the good material flow. The suitable of new plant layout can decrease the distance of material flow, which rises production.

Saifallah Benjaafar^[2], present a formulation of the plant layout problem where the objective is to minimize work-in-process by designing layout using a queuing-based model can be very different from those obtained using conventional layout procedures.

Amine Drira, proposed a various formulations of the facility layout problem and the algorithms for solving this problem^{[3][4]}: as it known to have a significant impact upon manufacturing costs, work in process, lead times and productivity.^[1]A good placement of facilities contributes to the overall efficiency of operations and can reduce until 50% the total operating expenses (Tompkins 1996). Simulation studies are often used to measure the benefits and performance of given layouts.

Stefan Bock^[5], Proposed an integrated approach which allows a more detailed layout planning by simultaneously determining machine arrangement and transportation paths. Facilities to be arranged as well as the entire layout may have irregular shapes and sizes. By assigning specific attributes to certain layout subareas, application-dependent barriers within the layout and making mathematical calculations new layout design made to improve transportation path.

In order to obtain a competitive level of productivity in a manufacturing system^[5], efficient machine or department arrangements and appropriate transportation path structures are of considerable importance. By defining a production system's basic structure and material flows, the layout determines its operational performance over the long term. By design plant layout structure^[5], gives integrated approach which allows a more detailed layout planning by simultaneously determining machine arrangement and transportation paths, this approach supports a detailed mapping of irregular, but fixed machine shapes.

Eida Nadirah Roslin and Ong Gee Seang^{[6][7]}, developed a specific design of facility layout for a production line by using the WITNESS simulation software for lubricant manufacturing company. Collected data would be sorted out and used as details in the WITNESS interactive simulation software. Two models of layout design will be built based on the data provided by using this software. The best layout will be recommended to be implemented at the production line in the chosen company. Implementation of a new facility layout is a very time consuming process and it requires a huge investment in order to implement all of the identified changes. Although no practical analysis is conducted to observe the implementation of the new layout made.

W.Wiyaratn and A. Watanapa^[8], study plant layout of iron manufacturing based on the systematic layout planning pattern theory (SLP) for increased productivity. The detailed study of the plant layout such as operation process chart, flow of material and activity relationship chart has been investigated. The new plant layout has been designed and compared with the present plant layout. The SLP method showed that new plant layout significantly decrease the distance of material flow from billet cutting process until keeping in ware house.

R. Jayachitra and P. S. S. Prasad^[10], study the suitability of a virtual cellular layout (VCL) along with an existing functional layout (FL) of an industry and a classical cellular layout (CL), if considered for implementation. A Genetic algorithm (GA) based intra-cell formation procedure is used in the cellular layout design. To identify the suitability of a particular layout in a given environment, a typical manufacturing system is modeled using the WITNESS 2006 simulation software. Design of experiments (DOE) is used to plan the simulation experiments.

Taho Yang^[11], explores the use of Multiple-attribute decision making methods MADM approaches in solving a layout design problem. The proposed methodology is illustrated through a practical application from an IC packaging company. Two methods are proposed in solving the case study problem: Technique for order preference by similarity to ideal solution (TOPSIS) and fuzzy TOPSIS. Empirical results showed that the proposed methods are viable approaches in solving a layout design problem. TOPSIS is a viable approach for the case study problem and is suitable for precise value performance ratings. When the performance ratings are vague and imprecise, the fuzzy TOPSIS is a preferred solution method.

Dhamodharan Raman^[12], proposed measurement model to determine the facilities layout's effectiveness by considering all significant factors. A measurement model considering a set of three layout effectiveness factors—facilities layout flexibility (FLF), productive area utilization (PAU) and closeness gap (CG). The proposed model will enable the decision-maker of a manufacturing enterprise to analyze a layout in three different aspects, based on which they can make decision towards productivity improvement.

Sukanto Bhattacharya^[13], proposed a semi-heuristic optimization algorithm for designing optimal plant layouts in process-focused manufacturing/service facilities. Proposed algorithm marries the well-known CRAFT (Computerized Relative Allocation of Facilities Technique) with the Hungarian assignment algorithm. Being a semi-heuristic search, algorithm is more efficient in terms of computer CPU engagement time as it tends to converge on the global optimum faster than the traditional CRAFT algorithm - a pure heuristic.

C.N. Potts and J.D. Whitehead^[14], considers combined scheduling and machine layout problems in a flexible manufacturing system (FMS). A three-phase integer programming model is derived. The first phase balances the machine workload by assigning operations to machines. The second phase minimizes inter-machine travel, while respecting the workload balance attained in the first phase. In the third phase, machines are assigned to positions in the loop layout so that the total number of circuits made by the products is minimized. It is shown that this phase can be modelled as a linear ordering problem.

3.Preliminaries Of Layout Planning

Before the layout of the plant is developed, the owner of the business must first develop a production program. It involves determining the product^[6], its sales location and its production location in order to maximize revenue. The next step is to decide the positioning or standard of the product. The strategic considerations of the company include whether to produce at a high volume and sell at low price, or to produce at a low volume but charge at a high price because it may be a high quality product. Once these details are confirmed, the planning of the layout may begin to minimize the cost of production. During the initial planning of a facility layout, there are two major issues to consider. The first issue is the overall space of the plant and how much the equipment needs space. The second is the internal traffic of the facility. This includes the logistics of the production and the worker's movements within the firm. When the initial planning stage is complete, there are three major steps to follow. These are information, strategy, and layout. The first step of gathering information is basic but important. During this step, it is necessary to calculate production time of the products. The calculation involves identifying the number of workstations required, the number of workers per department, and the bottlenecks. The strategy is the main focus on the layout because a company needs to know how to perform better than their competitors. This is the step where the company needs to structure the facility to obtain any absolute or competitive advantage over its competitors. Lastly, the layout is developed. This step requires planning the following: space planning, material flow, constraints, walking areas, etc.

4. Definition Of Layout Problems

A facility layout is an arrangement of everything needed for production of goods or delivery of services. A facility is an entity that facilitates the performance of any job. It may be a machine tool, a work centre, a manufacturing cell, a machine shop, a department, a warehouse, etc. (Heragu, 1997). Due to the variety of considerations found in the articles, researchers do not agree about a common and exact definition of layout problems. The most encountered formulations are related to static layout problems. Koopmans and Beckmann were among the first to consider this class of problems, and they defined the facility layout problem as a common industrial problem in which the objective is to configure facilities, so as to minimize the cost of transporting materials between them. Drira and Henri Pierreval considered that the facility layout problem consists in finding a non-overlapping planar orthogonal arrangement of n rectangular facilities within a given rectangular plan site so as to minimize the distance based measure. Azadivar and Wang (2000) defined that the facility layout problem as the determination of the relative locations for, and allocation of, the available space among a given number of facilities. Lee and Lee (2002) reported that the facility layout problem consists in arranging n unequal-area facilities of different sizes within a given total space, which can be bounded to the length or width of site area in a way to minimize the total material handling cost and slack area cost. Shayan and Chittilappilly (2004) defined the facility layout problem as an optimization problem that tries to make layouts more efficient by taking into account various interactions between facilities and material handling systems while designing layouts. Numerous articles have been published in this area. In fact, the problems addressed in research works differ, depending on such factors as: the workshop characteristics (e.g. ail, specificities of the manufacturing systems, the facility shapes, the material handling system, and the layout evolution), what is the problem addressed (e.g., problem formulation, objectives and constraints) and the approaches used to solve it (Resolution approaches). Although this tree representation can probably be improved in future research works, we have found it helpful in characterizing existing research works. Consequently, the rest of this article is organized in accordance with this representation and with the most important features identified.

5. Workshop Characteristics Impacting The Layout

Several types of workshop are addressed in the literature. In fact, the layout problems addressed are strongly dependent on the specific features of manufacturing systems studied. Several factors and design issues clearly differentiate the nature of the problems to be addressed, in particular: the production variety and volume, the material handling system chosen, the different possible flows allowed for parts, the number of floors on which the machines can be assigned, the facility shapes and the pickup and drop-off locations. Due to their importance, these factors are detailed below.

5.1. Products Variety And Volume

The layout design generally depends on the products variety and the production volumes. ^[6]Four types of organization are referred to in existing articles, namely fixed product layout, process layout, product layout and cellular layout. These key organizations are sometimes discussed differently according to the authors. In Fixed product layout, the products generally circulate within the production facilities (machines, workers, etc.); in this particular type of layout, the product does not move, it is the different resources that are moved to perform the operations on the product. This type of layout is commonly found in industries that manufacture large size products, such as ships or aircrafts. Process layout groups facilities with similar functions together (resources of the same type). This organization is often reported to be suited when there is a wide variety of product. Product layout is used for systems with high production volumes and a low variety of products. Facilities are organized according to the sequence of the successive manufacturing operations. In Cellular layout, machines are grouped into cells, to process families of similar parts. These cells also need to be placed on the factory floor. Therefore, one is also generally concerned with so called intra cells machine layout problems, with finding the best arrangement of machines in each cell.

5.2. Facility Shapes And Dimensions

Two different facility shapes are often distinguished, regular i.e., generally rectangular and irregular, i.e., generally polygons containing angles. A facility can have given dimensions, defined by a fixed length (L_i) and a fixed width (W_i). In this case, the facilities are called fixed or rigid blocks. A facility can also be defined by its area, its aspect ratio: $a_i = L_i/W_i$.

5.3. Material Handling Systems

A material handling system ensures the delivery of material to the appropriate locations. Material handling equipment can be conveyors (belt, roller, wheel), automated guided vehicles (AGV), robots, etc. Tompkins et al. (1996) estimated that 20–50% of the manufacturing costs are due to the handling of parts and then a good arrangement of handling devices might to reduce them for 10–30%. When dealing with a material handling system, the problem consists in arranging facilities along the material handling path. Two dependent design problems are considered: finding the facility layout and selecting the handling equipment. The type of material-handling device determines the pattern to be used for the layout of machine and that the facility layout also impacts the selection of the handling device. Given the difficulty of solving both problems jointly, they are mainly solved sequentially. Among the major types of layout arrangement based on the type of material handling, one can distinguish single row layout, multi-rows layout, loop layout and open-field layout ^[3]. The single row layout problem occurs when facilities have to be placed along a line. Several shapes may be considered from this basic situation, such as straight line, semicircular or U-shape. The loop layout problem deals with the assignment of m facilities to candidate locations $1 \dots m$, in a closed ring network, around which parts are transported in one direction. The loop layout incorporates a Load/Unload (L/U) station, i.e., location from which a part enters and leaves the loop. This station is unique and it is assumed to be located between position m and 1 . The multi-rows layout involves several rows of facilities (Hassan, 1994). The movements of parts occur between facilities from the same row and

from different rows. The open field layout corresponds to situations where facilities can be placed without the restrictions or constraints that would be induced by such arrangements as single row or loop layout.

5.4. Multi-Floor Layout

Nowadays, when it comes to construct a factory in urban area, land supply is generally insufficient and expensive. The limitation of available horizontal space creates a need to use a vertical dimension of the workshop. Then, it can be relevant to locate the facilities on several floors, so that parts can move horizontally on a given floor (horizontal flow direction), but also from one floor to another floors located at a different level (vertical flow direction). The vertical movement of parts requires a vertical transportation device: elevator. In such situations, both the position on the floor and the levels have to be determined for each facility, so that the related problems are referred to as multi-floor layout problems seems to be among the firsts to address a multiple-floor layout problem. He dealt with the problem of defining relative locations of facilities in a multiple-floor building. Later, other researchers focused on taking into consideration vertical movements of parts from one floor to another. Elevators are often the material handling system reported. Their number and location are either known or to be determined through optimization. The number of floors can be known (Lee et al., 2005) or to be determined, depending on each floor area and on the number and dimensions of the facilities.

5.5. Backtracking And Bypassing

Backtracking and bypassing are two particular movements that can occur in flow-line layouts, which impact the flow of the products. Backtracking is the movement of a part, from one facility to another preceding it in the sequence of facilities in the flow-line arrangement. The number of these movements has to be minimized. This problem Production Line Formation Problem (PLFP), which consists in determining the orders (partial or total) of machines so as to minimize the weighted sum of arrows whose direction is contrary to the global flow of products, while taking into account constraints on the rank of machines. Bypassing occurs when a part skips some facilities during its moving towards the flow line arrangement noticed that several procedures were presented for dealing with and minimizing backtracking but no procedure was suggested in the literature for addressing bypassing.

5.6. Pick-Up And Drop-Off Locations

It is often necessary to determine the location from which parts enter and leave facilities, called Pick-up and Drop-off (P/ D) points. Although they can potentially be located at various places, several researchers restricted their possible position to reduce the complexity. The objective can be to determine a layout for each period in the planning horizon, while minimizing the sum of the material handling costs, for all periods, and the sum of the rearrangement costs between time periods. Rearrangement costs have to be considered when facilities need to be moved from one location to another.

6. Methods And Techniques To Facility Layout Planning

In order to obtain a competitive level of productivity in a manufacturing system, efficient machine or department arrangements and appropriate path structures are of considerable importance. By defining a production system's basic structure and material flows, the layout determines its operational performance over the long term. However, various methods and techniques are proposed to get optimum layout at a more detailed level.

6.1. Multiple Attributes Decision Making Method

The layout design problem is a strategic issue and has a significant impact on the efficiency of a manufacturing system. Much of the existing layout design literature that uses a surrogate function for flow distance or for simplified objectives may be entrapped into local optimum; and subsequently lead to a poor layout design due to the multiple-attribute decision making (MADM) nature of a layout design decision. The present study explores the use of MADM approaches in solving a layout design problem.

Methods used in solving plant design problem: Technique for order preference by similarity to ideal solution (TOPSIS).

A MADM problem can be concisely expressed in a matrix format, in which columns indicate attributes

considered in a given problem; and in which rows list the competing alternatives. Specifically, a MADM problem with m alternatives (A_1, A_2, \dots, A_m) that are evaluated by n attributes (C_1, C_2, \dots, C_n) can be viewed as a geometric system with m points in n -dimensional space. An element x_{ij} of the matrix indicates the performance rating of the i th alternative, A_i , with respect to the j th attribute, C_j .

Taho Yang, Chih-Ching Hung^[15], developed TOPSIS based on the concept that the chosen alternative should have the Shortest distance from the positive ideal solution and the longest distance from the negative ideal solution. More detailed information can be found in (Taho Yang, Chih-Ching Hung) . The terms used in the present study are briefly defined as follows:

- Attributes: Attributes ($C_j, j = 1, 2, \dots, n$) should provide a means of evaluating the levels of an objective. Each alternative can be characterized by a number of attributes.

-Alternatives: These are synonymous with 'options' or 'candidates'. Alternatives ($A_i, i = 1, \dots, m$) are mutually exclusive of each other.

-Attribute weights: Weight values (w_j) represent the relative importance of each attribute to the others.

$W = \{w_j | j = 1, 2, \dots, n\}$.

-Normalization: Normalization seeks to obtain comparable scales, which allows attribute comparison. The

Vector normalization approach divides the rating of each attribute by its norm to calculate the normalized value of x_{ij} .

Given the above terms, the formal TOPSIS procedure is defined as follows:

Step 1: Calculate normalized rating for each element in the decision matrix.

Step 2: Calculate weighted normalized ratings. The weighted normalized value v_{ij} is calculated by Eq. (3).

$$v_{ij} = w_j r_{ij} \quad ; i = 1; \dots m; j = 1; \dots n. \quad (3)$$

Step 3: Identify positive ideal (A^*) and negative ideal (A_-) solutions. The A^* and A_- are defined in terms of the weighted normalized values.

6.2. Transportation Path Design Method

This method introduces an integrated approach which allows a more detailed layout planning by simultaneously determining machine arrangement and transportation paths^[16]. Facilities to be arranged as well as the entire layout may have irregular shapes and sizes. By assigning specific attributes to certain layout subareas, application-dependent barriers within the layout can be incorporated. It introduces a new mathematical layout model and develops several improvement procedures. An analysis of the computational experiments shows that more elaborate heuristics using variable neighborhoods can generate promising layout configurations.

Mathematical definition of the new layout model providing a combined machine-arrangement and material flow determination is presented. In order to make it more readily comprehensible, this definition starts with a separate definition of the given parameters, followed by the introduction of the variables to be determined, after which the restrictions and objective function are given.

The following parameters are used in the mathematical model:

• N —Number of machines or machines/departments to be located or reallocated in the layout [–]

• X —Number of unit-elements within a horizontal plane [–]

X defines the number of existing unit-elements in the horizontal direction, numbered from 1 to X .

• Y —Number of unit-elements within a vertical plane [–]

Y defines the number of existing unit-elements in the vertical direction, numbered from 1 to Y .

To provide a uniform physical distance between the centers of all adjacent unit-elements in the layout, a rectangular neighborhood definition is used. Here, the unit-element $(x, y) \in \{1, \dots, X\} \cdot \{1, \dots, Y\}$ is adjacent to $(x_0, y_0) \in \{1, \dots, X\} \cdot \{1, \dots, Y\}$ if and only if one of the following restrictions is fulfilled: (i) $x = x_0 - 1$ and $y = y_0$, (ii) $x = x_0 + 1$ and $y = y_0$, (iii) $x = x_0$ and $y = y_0 - 1$, or (iv) $x = x_0$ and $y = y_0 + 1$.

In addition, a set E of unit-elements is denoted as contiguous, if and only if for each pair $e_1, e_2 \in E$ there is a sequence of t (P_2) unit-elements $(e_1, e_2, \dots, e_t) \in E$ fulfilling the following restrictions: (i) " $i \in \{1, \dots, t-1\}$: e_i and e_{i+1} are adjacent, (ii) $e_1 = e_1$, and (iii) $e_t = e_2$.

• C —Number of conditions [–]

C is the number of predefined application-dependent conditions fulfilled by the defined coordinates in the layout in question or required by the machines to be allocated. These conditions are numbered in a predefined sequence from 1 to C .

• F_n ($1 \leq n \leq N$)—Number of unit-elements belonging to the n th machine [–].

• $Rest_{x,y}$ ($1 \leq x \leq X; 1 \leq y \leq Y$)—Binary constant defining whether the unit-element with the coordinates (x, y) is a restricted element [–].

A restricted element cannot be covered by a machine or transportation-path. Restricted elements can be interpreted, for instance, as walls, stairs or other barriers. Note, that the introduction of restricted elements allows an exact mapping of layouts not being rectangular. In this case X and Y are determined by the side lengths of the minimum rectangular cover. This may cause some unrestricted elements to become restricted.

6.3. Systematic Layout Planning (SLP) Technique

In these technique data were collected and the number of tools/ equipment for manufacturing was counted in terms of the direction for raw materials and product. The operation process chart, flow of material and activity relationship chart have been used in analysis. The problem of the plant was determined and analyzed through SLP method to plan the relationship between the equipments and the area. The framework of SLP^[18] is shown in Fig. 1. 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 foundry production, the relation between each operation unit can be observed. Then the results were drawn through the comparison between the existing manufacturing process and the proposed way.

6.4. Simulation Technique

In the past, there were many techniques to design industrial plant layout. The most popular was CRAFT (Computerize Relative Allocation Facilities Technique). However, the result from CRAFT was limited. The result of design showed only minimum total transfer cost between departments. As a result, the simulation technique is added to plant layout design to show more information about the design such as total time in system, waiting time, and utilization^[17].

The calculation of simulation is based on the following equations:

$$\text{Minimize } C = \sum_{i=1}^n \sum_{j=1}^n f_{ij} c_{ij} d_{ij} \quad \dots \dots \dots (1)$$

C : Total Transfer Cost

f_{ij} : Transfer Rate From i To j

c_{ij} : Cost of Transfer From i To j

d_{ij} : Distance From i To j (From Centroid)

If the distance between departments is rectilinear, d_{ij} is calculated based on Equation (2).

$$d_{ij} = \Delta x + \Delta y \dots\dots\dots(2)$$

If the distance between departments is euclidean, d_{ij} is calculated based on Equation (3).

$$D_{ij} = \sqrt{(\Delta x)^2 + (\Delta y)^2} \dots\dots\dots(3)$$

To calculate the distance between departments, centroid of each department is calculated using equation (4) and (5).

$$X = 1/A \int \int x dx dy = 1/(2A) (X_2 - X_1 \times Y_2 - Y_1) \dots\dots\dots(4)$$

$$Y = 1/A \int \int y dy dx = 1/ (2A) (Y_2 - Y_1 \times X_2 - X_1) \dots\dots\dots(5)$$

Based on these calculations, the result design will show only a transfer cost between departments. The good result design means less transfer cost between departments. However, there are other parameters missing such as total time in system, waiting time, or utilization.

7. Software To Facility Layout Planning

Optimization in a facility has become one of the primary objectives for each company. The time needed to plan an optimized facility has been decreasing throughout the last decade because of computer technology. There are many software programs written to allow one to develop a facility layout in a short amount of time. In this section, three software will be described, and explained why they are useful. The software that will be introduced are: LayOPT, FLQ and WITNESS.

7.1. LayOPT

LayOPT^[6] is software used to solve layout problems in manufacturing plants, warehouses or offices. The inputs required to use the software are: flow data and cost data. The flow data includes the number of departments, cycle times and the process flow. Cost data includes the raw materials cost, cost per unit of production and other costs associated with the process. LayOPT has two types of algorithm: improvement and construction. The construction algorithm is used when starting to design the initial layout. However, most users prefer to use the improvement algorithm of LayOPT to edit an existing layout rather than to produce a new one (Narayanaswamy). Before LayOPT was developed, improvement algorithms were not used commonly because it was too costly to overcome constraints such as the size of the facility or how departments interacted with one another. This software’s main advantage is to allow a user to improve an initial layout using block diagrams. From the block diagram, LayOPT analyzes each department’s communication and frequency of interacting with each other. The software reorganizes the initial layout, making interaction between each department simpler. The software perform that function by minimizing an objective function, which is the sum of parts flow multiplied by unit costs and the distances over which these parts travel. When two departments are being compared, the value of the department’s importance or purpose is assigned by the user. The goal of the program is to minimize the difference in each department’s value. The layout is optimized if a difference of zero is achieved.

When a user activates the optimization tool on LayOPT, the software has an automatic mode and an interactive mode. In the automatic mode, the program searches for every possible department combinations and reports the best results for interaction. The process continues until the objection function is optimized. With this option, a user can see a long run plan of the company and the expansion potentials of the layout.

The interactive mode is used when the facility’s department relocation costs are high. LayOPT then develops options for incremental changes for the facility from its current layout. It presents the top ten changes that maximize the plant fitness as measured by the objective function. If the user selects a location exchange between two departments, the resulting layout is reevaluated and LayOPT will redevelop another list of top ten options for the user to evaluate. Below the window displays what the software looks like when using the interactive mode. In the “Run” tab, it shows each department and its optimal pairing, meaning which departments should be placed together to lower costs.

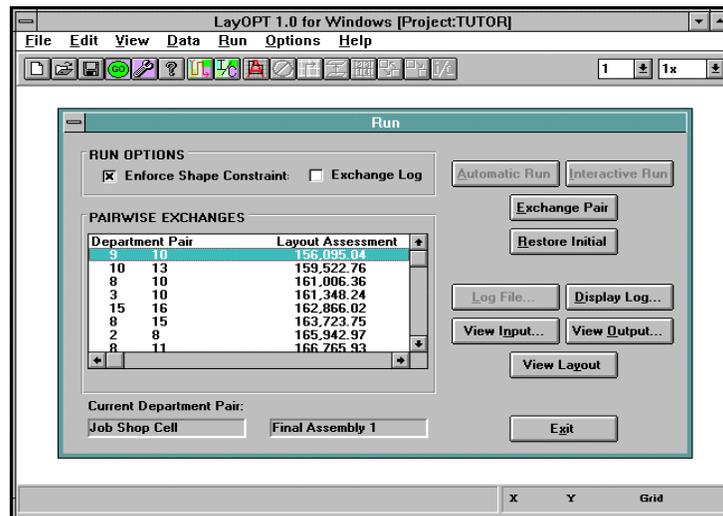


Figure 1: Example Of The Interactive Run Displaying The Top Ten Optimal Solutions

7.2.FLQ

The FLQ^[6] (Facility Layout with Queuing), (Yang & Benjaafar, 2001) software is an application that includes traditional layout design and queuing. The advantage of this program is that it provides information and optimizes transportation of materials and products between departments. The software allows the user to obtain and optimizes the following information:

- Product processing times
- Product production requirements
- Number of departments required to process product
- Material handling systems
- Holding costs
- Design criteria

Before FLQ can give the optimum solution of the plant layout, the user must input data into the software first. The types of data needed departments, products, facility sizes, material handling systems and layout configuration information. The department data only includes the name and the number of departments. The time that is required for that specific department to complete one unit is not part of the data. Figure 2 shows department data window allowing user to input name and number of departments.

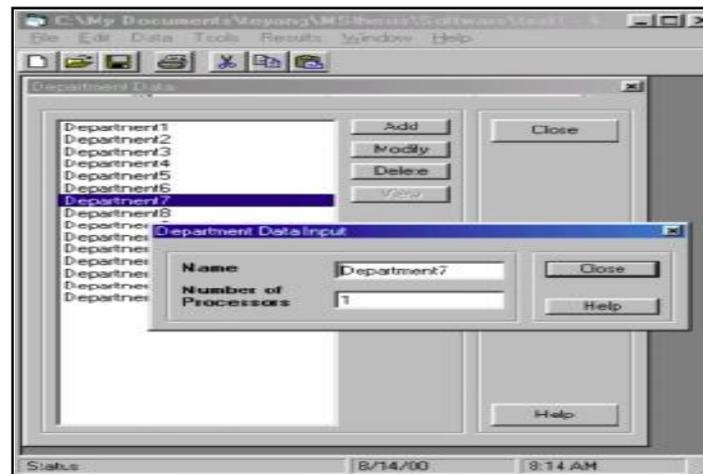


Figure 2: Department Data Window Allowing User To Input Name And Number Of Departments

Product data requires more information than department data. Other than the product name, the user has to enter the target lead time and production department, as well as penalty costs if lead time is not met. The information inputted should be as accurate as possible; changes can be made in the program if not correctly entered initially.

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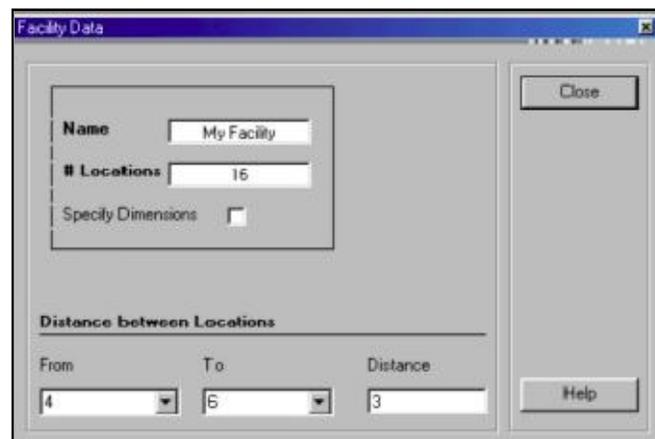


Figure 3: Facility Data Window And Inputting The Distance And Destination

Facility data is as simple as department data. Only the number of locations and the distance between them are required. The layout will then be represented as block diagrams. Here, the user may input the dimensions of the facility in a window. In the materials handling window, the user must choose if the facility is using a centralized or decentralized system. The difference between these

two systems is where the product's end location is. When using a decentralized system, the product stays where it was last placed. In a centralized system, the product returns to a central location after delivery (Yang & Benjaafar, 2001). This software's default system is decentralized unless the user changes it. The reason is because most facilities usually have their products shipped from the raw material department to the finishing line. A centralized location where a finished product is always delivered to requires a lot more space to implement.

After all the information has been inputted, the program can show various operational performances in a menu. This is seen under a menu called "results" and they are categorized as: departments, products, material handling, flow and time between departments.

7.3. WITNESS Simulation Software

WITNESS^[17] is Lanner Group's simulation software package. It is the culmination of more than two decades of experience with computer-based simulation. WITNESS simulation software is one of the simulation software that can be used to analyze the plant layout. This software is capable of producing high accuracy models for both discrete and continuous systems. This software also can

provide information to predict outcomes, identify bottlenecks, analyze problems, and formulate solutions. It is also able to provide immediate feedback under certain predetermined conditions (Markt et al. 1997). By using WITNESS simulation software^[17], a prototype model of new plant layout can be generated and used for evaluations.

8. Conclusion

Industries nowadays realize that a good facility layout is essential to efficiently produce products and compete successfully in the market. As mentioned earlier in this report, there are factors to consider when designing a facility layout. The most important factors are the location and the machinery or capital investment. The reason is because capital investment requires a large amount of money. If layout planning is done poorly, the company would have a loss and it could affect its growth. Even if the correct machinery were bought, maintenance costs could be high. The building location is important depending on where the consumers are. In addition to allowing customers to find the company, it must be able to ship its products to the customers. Having the company close to customers is another way to save money by reducing shipping and transportation costs. With the technologies available to everyone, coming up with an efficient layout is taking less time than before. However, one must remember that with more facilities built, competition intensifies. Even when an optimal layout is developed, the amount of labor needs to be sufficient. Having too much workers could result in less profit because of waiting time or bottlenecks. Each workstation should have an optimal amount of workers.

It is recommended that the human resources, efficient materials use, and visual control be improved in any given facility. Working conditions of employees should be analyzed. Temporary workers and regular workers whose salaries are based on productivity would usually not agree on improvement programs because they do not get the benefits of doing so. New employees should sign a contract agreeing that salaries will increase depending on productivity. With a revenue sharing or incentive based contract, efficiency improvements will become part of the workers' requirements. When developing a relationship with the supplier, not only is the purchasing, delivery and inspection the important things to consider, the supplier should also ensure goods are delivered on time and must fully understand that the products are needed for the company. Inventory should be reduced as much as possible as well.

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