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Designing Facilities Layout for Small and Medium Enterprises

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Abstract— — Facilities layout is a systematic and functional arrangement of different departments, machines, equipments and services in a manufacturing establishment. It is vitally important to have a well developed plant layout for all the available resources in an optimum manner and get the maximum out of the capacity of the facilities. The problem is of particular importance for Small and Medium Enterprises (SMEs) because of major constraints that include cost and space. Selection of right method is a very important step in layout design. In this paper methods of layout design are discussed taking into consideration the specific issues and limitations of SMEs.

Keywords— Facilities Layout; Layout Problems; Computer Aided Layout Planning; Evaluation Methods, Simulation

INTRODUCTION

The most crucial element that affects efficiency of a production process is the facilities layout. A good layout keeps costs low and reduces unnecessary material handling while maintaining the product flow through the facility. Improving the layout also increases the machine utilization that enhances the machining capacity of the shop floor. Quite often, the management feels the need of redesigning plant layout even when the things are apparently going smoothly for the company. One of the reasons for designing a new layout may be improving the performance of the existing plant. Upgrading the facility by replacing old facility with more advanced machinery is also necessitated many a times [1]. In both the cases the performance measures being targeted for improvement need be identified clearly.

An enterprise is considered as an SME based on the annual sales turnover or number of full-time employees of a unit which is a small number, not exceeding 50. The majority of workers are invariably semi-skilled and required to work on more than one machine. Most of SME faces the problem of unsafe movement of operator from one machine to another. It is desired to arrange the machines in such a way that single operator can easily and safely move to number of machines [2]. Improving the layout to get better utilization of machine and operator need lean thinking. Redesigning an existing layout calls for a critical consideration of several key factors including the 13 factors suggested by Apple [3].

The common thing about the all available methods of plant layout development is that they develop number of alternate layouts. The selection of best among these layouts is based on certain evaluation methods. Each plant layout design technique has its own and different evaluation method. Each evaluation method is based on single performance measure. It is therefore very necessary to decide and fix the performance measure has to be improved for designing a new plant layout. The objective of the layout design has to be very clear as it helps in deciding the best method to implement for improved layout design. Further, one must evaluate the proposed layout and compare it with existing layout, based on the chosen performance criterion. In SME's the nature of plant dynamic i.e. there is frequent change in the demand and scheduling is very complicated. Measuring the performance becomes very difficult by direct mathematical calculations. Use of simulation tools for measuring the performance is suggested by some investigators [4].

It is seen that for designing a new layout it is very important to know the problems faced by the SMEs, the available techniques of layout design, use of simulation in layout design and evaluation methods. These are discussed next.

LAYOUT PROBLEMS

The facility layout problem is concerned with finding the most efficient arrangement of individual departments with unequal area requirements within a machine or facility. The objective of the facility layout problem in SME, therefore, is to minimize the material handling costs inside a facility subject to two sets of constraints: (1) department and floor area requirements and (2) department location restrictions. These constraints include:

1 Departments should not overlap
2 .All departments must be located within the facility
3 Location of some departments is pre-fixed due to processing sequence
4 Some sections are not allowed to be placed adjoining specific locations
5 Floor loading and
6 Floor-to-ceiling clear-height in multiple-floor facilities. [5]

Earlier the facility layout is considered to be static, that is once the layout is planned and executed it is not changed for many years. Now a days that trend is changed, with continues improvement in the technology management had to update the facilities with time. The task of designing a dynamic layout becomes even more difficult when multiple objectives have to be achieved. [6][7]

With the increasingly diversified demand in the production, most of the manufacturers are using mixed-product assembly lines (MPAL's). The design of the assembly line has to take this evolution into account. An MPAL is a production line capable of producing a variety of different product variants simultaneously and continuously. Stations are flexible enough to perform their respective tasks on different variants. The most common problems seen with MPAL's are:
1. Generic product modelling,
2. Line balancing,
3. Resource planning, and
4. Resources allocation to the workstations in order to balance the workload along the line.

Resource planning is concerned with the selection of production means which are adequate for performing the assembly operations specified by the assembly planning. Model launch is based on schedule of the different models to be produced during the course of work shift. [8].

Bottleneck is one of the major problems faced by most SMEs in manufacturing parts that necessitate machining operations. Reason of occurrence of bottleneck is mainly due to improper sequencing of facilities within the work area. Bottlenecks should be eliminated in any operation because it severely affects productivity and throughput improvement of the plant. [9]

The facility layout problem is a common industrial problem in which the objective is to configure facilities so as to minimize the cost of transporting materials between machine tools and other processing operations such as welding. Fig. 1 highlights what seems to constitute essential features to characterize layout problems [10].

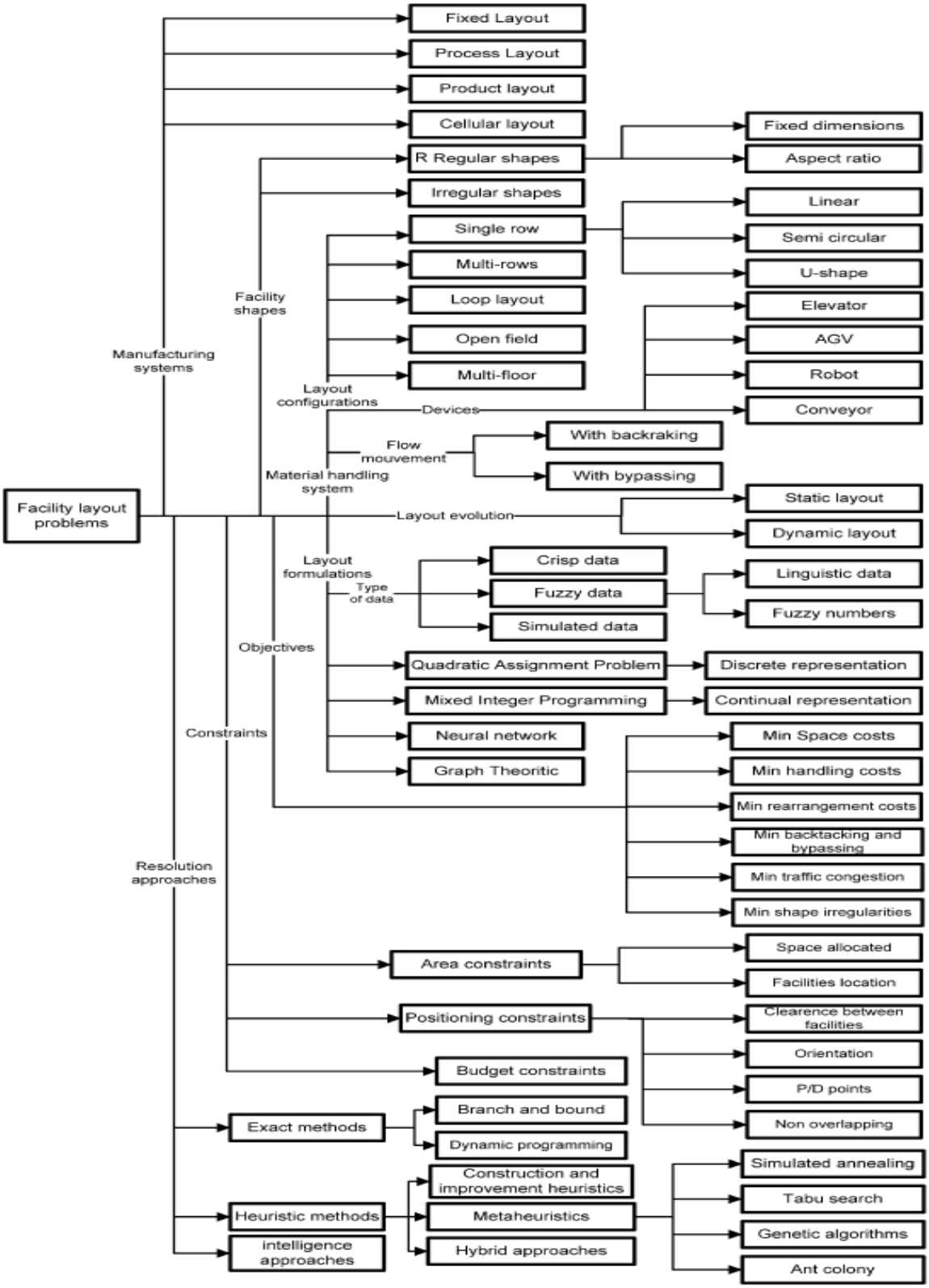

Fig. 1 Tree representation of the layout problems [10].

LAYOUT DESIGN TECHNIQUES

Plant layout design is very old concept and considerable research has already been done in this area. With the time elapsing, various techniques and software tools are now available. The following are some of the well known techniques currently employed for the plant layout design.

Manual Method

Traditionally, scale templates of various departments are prepared as per dimensions or area requirement and are adjusted by the designer in the available space. The effectiveness of this method is dependent on the designer's experience and judgment. This method is, therefore, not being preferred these days for designing a layout.

1. Systematic Layout Planning (SLP)

Muther [3] has proposed a methodology to design plant layout based on analysis, search and selection procedure as shown in fig. 2. The alternative layouts generated by this method are based on block diagrams. The space relationship diagram is constructed by replacing the unit squares with space templates. For each activity, a space template is constructed to scale, to represent the size and shape of the activity. Since different shapes can have same area, it is possible to construct different space relationship diagram from the same block diagram. This method also relies heavily on the capabilities of the designer. It can, however, prove quite effective if proper care is taken in arranging the templates.

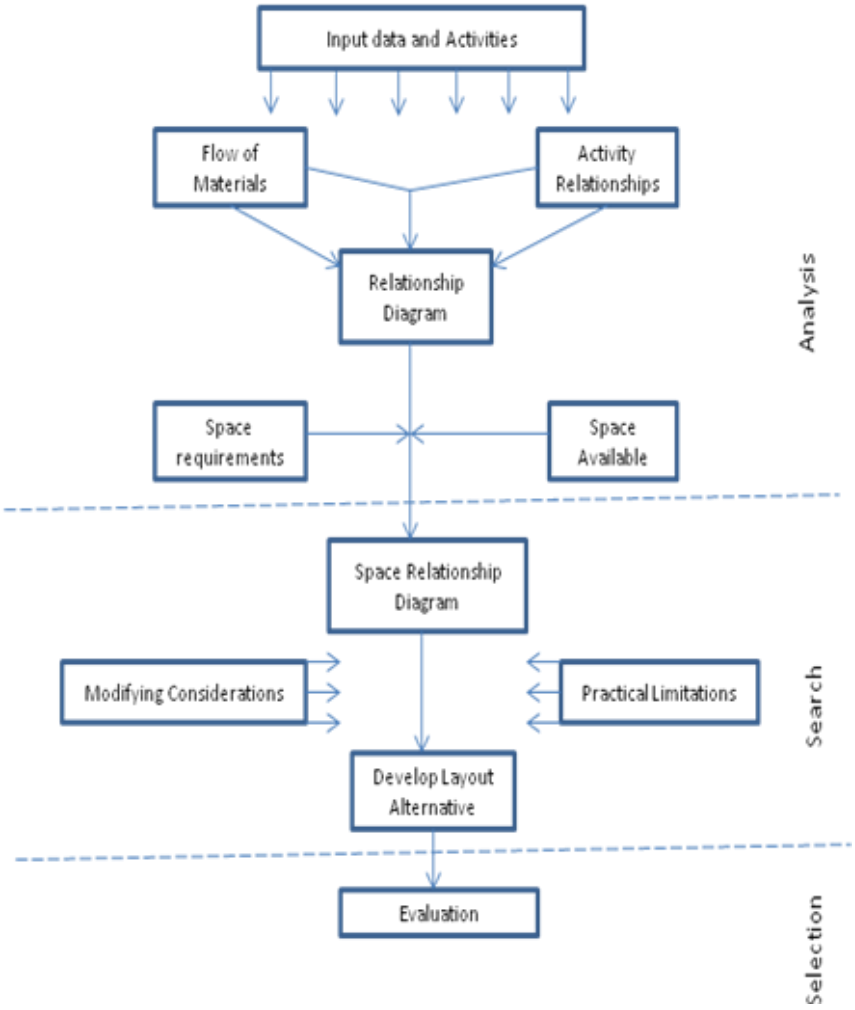

Fig 2. Systematic layout planning [3]

An important consideration in plant layout design is the human comfort. This should be maximized while minimizing at the same time the distance between the facilities. The human factors which need attention in developing machining facilities include work environment with human body posture, stress and other physiological capacities of the work force. Successfully achieving such human factors enables good working conditions which are conducive for reduction in injuries, effective and highly productive environment and reduced fatigue. It is found that these goals are fairly well achieved by using SLP that takes into consideration the human factors [11]. The SLP has been found to improve spatial distances between facilities (machines, between workstations and between departments) and also improve the flow of material through the plant. Thus cost of material handling is reduced significantly [12]. As a consequence, less material handling time is needed, workers move faster and the overall productivity increases. [9][13][14][15]

Computer Aided Plant layouts

1. **ALDEP (Automated Layout Design Program)**

ALDEP is construction based algorithm and is used when activity relationship is a major consideration. It develops a layout design by randomly selecting a department and placing in the layout [16]. The departments are placed in layout based on its closeness rating. Layouts are evaluated by adjacency score i.e. totaling the numerical values assigned for adjacent departments closeness rating. In the layout generated by ALDEP, departments have unusual shaped borders. Since evaluation is based on only one parameter, namely the effectiveness of the layout proposed, this method has not received good acceptance.

ALDEP is generally used for developing a new layout. It is not convenient for redesigning and improving the existing layout. It can, however, be of assistance in generating a large number of alternatives layout solutions all of which can then be evaluated separately. It is not found adequate for reducing the material travel distance across the plant.

2 CORELAP (Computerized Relationship Layout Planning)

CORELAP is also a construction algorithm with activity relationship a major consideration. It is designed to accommodate situations when constantly changing conditions prohibit the collection of precise numerical data. [16]

CORELAP constructs layouts by locating rectangular-shaped departments when the departmental area and layout scale permit a rectangular representation of the departmental area. It is based on REL chart and numerical weighted rating assigned to the closeness ratings. The evaluation phase employs a placing rating and a boundary length.

Total closeness rating for each department is calculated as:

$$TCR_i = \sum_{J=1}^{m} V(r_{ij})$$

m = no. of departments

The TCR rating is the sum weighted rating between the new department and its neighbors in the layout. Boundary length refers to the length of the boundaries common to the new department when all departments are accommodated in the layout.

CORELAP is a deterministic approach that provides an unique solution. Running the program second time with the same data produces the same final layout. The rectangular shape of the departments is divided into predefined number of square blocks. In order to make department rectangular the user has to increase or decrease the area of the department which results in over or under-utilization of the floor space. Unlike SLP the generation phase of the layout is carried by this technique without any involvement of the designer. Once the relevant input data and information is entered, the entire layout development work is fully performed by the program. There is a high possibly that layout generated by CORELAP is not practically implementable.

An updated version of CORELAP, named INTERACTIVE CORELAP, has been introduced recently to overcome these limitations. It allows the user to make fine adjustments at intermediate stage of the layout development. The layout generated by this version doesn't have rectangular configurations that eliminate poor space utilization exist in previous version. Evaluation is based on score which is the shortest rectilinear distance between the borders of all pairs of departments multiplied by the numerical values of the closeness rating between the departments. It gives more realistic layouts since the layout user is a part of the decision making process and operational difficulties can be taken care of to some extent due to possibility of intervention at the intermediate stage.

2. CRAFT (Computerized Relative Allocation of Facilities Technique)

CRAFT is based on improvement algorithm. It is applicable for improving performance of the existing plant. It is used when reducing the material handling cost is the main objective of layout design. The locations of activities (departments) are interchanged in the existing layout to improve the layout. CRAFT is a suboptimal, heuristic procedure which produces a layout that cannot be easily improved upon further.

Generation of layout is based on total distance traveled by the material. It first evaluates a given layout and then considers the effect if the department locations are interchanged. Only departments with common borders or of the same area are considered for exchanges of locations. If an improvement becomes visible due to pair wise exchange, the exchange producing the greatest improvement in chosen. The approach provides the flexibility of retaining the existing locations of certain departments in the layout being developed. This can be a matter of great convenience to SMEs. In a typical example of the job shop layout, it is shown that the revision has yielded a reduction of 52% in the total distance traveled by the product as compared to the earlier layout when replaced with the cell type layout generated by CRAFT [17]. The CRAFT can also be used in cell layout to solve the problem associated with the total material traveled. [18]

The use of CRAFT program does not guarantee that the least-cost layout will be found, since all possible interchanges are not considered. It is the most widely used technique for layout design. SME's in particular desire that the process of layout redesign is

quick and efficient since they cannot afford their limited human resource continue to remain unproductive for long periods of time. The changeover has to be executable quickly and at a little cost.

4. AUTO LAY 2010

It is software that generates plant layouts automatically and compares all layouts on the basis of their effectiveness and cost incurred. Inputs required are relationship code, relationship value and area of each department and equipment. First the user of the program has to input the relationship code which can be gathered from the relationship chart known as REL chart. By entering the area required by each department or facility program computes the number of unit square needed for each department. The computed numbers of squares are used to indicate each facility. Further, the user has to specify the relationship value allotted to each priority code. Program calculates the total closeness relationship value for each section and by combining these values the score of the existing layout is determined. Based on the specified closeness relationship value nodal diagram is generated. By replacing the nodes with the computed number of unit blocks alternate layout is developed. The effectiveness value and relative cost of the generated layout is computed. Similarly, an array of layouts is generated till an optimum effectiveness value and transportation cost combination is achieved. The following relationships may be used.

Generation of square blocks for grid:

No. of blocks (B) = A/q^2
A= area of dept.
q= block dimension

Distance effectiveness value:

$$\sum_{i=0}^{n} \sum_{j=0}^{m} G_{ij}\, d(k_i,h_j)$$

Where:
n, m = number of department in row, column
G_{ij} = Activity relationship rating
D = rectilinear Distance between station I and j.

Relative cost:

$$\sum_{i=0}^{n} \sum_{j=0}^{m} C_{ij}\, d(ki,hj)$$

where C_{ij} = Projected Transportation Cost of setting dept i beside j

If the designer desires to make any changes in the layout proposed by the program, he has the option to interchange nodes as deemed fit. The program allows for incorporating such changes. However, the program is unable to handle and accommodate all the constraints envisaged in designing a layout.

Application of AUTO LAY 2010 to an Aluminum product factory has shown that cost of transportation in has been reduced. With just 50% less movement cost, the new layout is now more efficient and cost effective [19]. Similar results have been observed when this tool is used for a process based firm. Its effectiveness for the product based firm, such as a typical machine shop, is required to be validated.

SIMULATION

The process of layout design is necessary in order to improve the performance of the existing layout or for solving certain problem related with the layout. To evaluate whether the said objectives would be achieved by the new layout, it is essential to measure the performance of the existing layout and the proposed layout. Static performance measures are easy to calculate by simple formulations. There are some measures which are time dependent that is the number of accidents, annual production level, number of batches waiting for processing and many more. These time dependant measures are not deterministic due to dynamic behavior of the plant [20]. The actual model building can take months and cost a company plenty of money. After modeling it may be found that the new layout doesn't meet the desired expectations. The process of layout design is required to be repeated until a satisfactory layout is obtained. Using simulation software is the way out to quickly model and test the layout economically.

One of the best tools available to provide correct evaluations of system interdependencies is discrete event simulation. With the use of this simulation technique, manufacturers are able to quickly and accurately model future proposed modifications to their facilities without making costly guesses. It saves time and money in modeling the layout, and enables testing the performance. The

models being created not only serve the initial purpose of determining buffer space and resource levels, but also permit evaluation of new cuttings on a regular basis [2][21]. This multi-functionality feature has turned the simulation models into an operational planning tool and has brought facilities planning directly to the plant floor where the everyday engineer can evaluate changes quickly and accurately. The multi-purpose plant model is now becoming the norm rather than a farfetched dream when evaluating new product flows on the plant floor [4].

The objective of the simulation exercise must also be clear. The focus primarily is on minimizing travel distance and material handling cost. Simulating the layout after design phase is better when applied to deterministic problems with predefined operational policies and production strategies. However, simulation, followed by design, is best applied for problems exhibiting uncertainties and those where the objective is to justify production strategies and improve layout operational parameters [22]. By observing the above, it can be readily seen that using simulation prior to and after the layout generation is the best approach. This provides for straight forward evaluation of the alternative layouts made a available by the program. One can chose the best layout based on the predefined objective or performance criterion [9].

DISCUSSION

Unquestionably, selection of proper technique is a very important step in the layout design. Every available technique has its own benefits and limitations. There is no method which can be a alchemy solution the entire layout problem. The selection of technique is dependent on the plant constraints, size of firm and objective of design. The final layout given by the computer program may not be best design, as computer programs are optimization techniques based on certain algorithms which may not be practical or those not able to take care of all the eventualities. The computer programs are better than the traditional methods as they form an array of layouts very quickly and are not dependent of capabilities of the designer. Performance of each alternate layout can be evaluated by simulation and one can select the most appropriate layout by comparing the performance of the each layout considering the objective of the layout design.

In this paper efforts have been focused on finding the most suitable method to design layout for SME's. As discussed earlier, the major constraints in the SME's are that they have limited capital and space. For choosing the best technique, the designer has to first think on whether the firm is product based or process based. Basically for product based firms minimizing the distance between the facilities along with maintaining smooth flow of material is considered. While for process based firm closeness relationship of a facility with all the other facilities is main concern. Comparatively more facilities are required to be accommodated in the available space. This means that the process of layout design should be simple and such that hiring a specialist layout designer becomes unnecessary.

The most common objective of layout design, that is to minimize distance traveled, is not always suitable for all the SME's. Some congestion in a specific area may have to be tolerated while maintaining minimum separation between facilities. Instead of criterion of minimizing total distance travelled, one may wish to minimize the maximum distance travelled [1].

CONCLUSIONS

It is noticed that the performance of SME's can be improved even with some redesigning the existing layout. A careful study can make it possible to just change the process layout into a cell layout. It is more beneficial to first form cells and then design a layout using CRAFT. For the SME's where cell formation is not possible, CRAFT can be used by replacing the department with facilities and layout of plant with departments. Working on this program is easy and simple. Anyone who has basic computing knowledge can work upon the problem of layout planning. The process of designing a layout for SMEs should be as follows: Collect the data; decide the objective of layout design; compute the performance of the existing layout using simulation; generate alternate layouts by using layout generation technique; again evaluate the performance of each alternate layout and select most optimal layout by comparing performances. SMEs would be benefited immensely if clear design procedures and simulation software are made available to them. Extensive application of simulation techniques is suggested for improving plant layout and enhances productivity.

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