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The Analysis of Facility Layout Planning in Factories

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Abstract: *The problem of facility layout planning has always been the focus of production logistics for the enterprise. In recent years, with the development of intelligent manufacturing, improvement of material processing efficiency, reduction of the materials storage time and increasement of the production efficiency have become more and more important, and a good facility layout design can help to realize them. The facility layout planning is one of the most critical parts among the production logistics for factories. This paper first puts forward the common problems of facility layout in factories, and then introduce facility layout problems and some solution methods, finally give some suggestions of facility layout in factories.*

Keywords: *Facility Layout Planning, Manufacturing, Factory*

1. Introduction

Facility layout planning is an important part of manufacturing system. Reasonable facility layout can not only reduce production cost, operation cost and maintenance cost, but also effectively improve the operation environment of production system and increase the reaction speed of enterprise.

In manufacturing enterprise, facility layout planning in production logistics has always been the focus of enterprise. According to statistics, 20%-50% of the total operation cost in manufacturing is caused by the unreasonable layout of facilities. If the layout design of facilities is optimized, the cost should be reduced to 15%-30% to improve the efficiency of production [1]. In the logistics activities of production enterprises, from the arrival of raw materials to the delivery of finished products, the processing time materials only accounts for about 10% of the production cycle, while the rest of the time is in the state of transportation or storage. However, a good facility layout design can improve the material processing efficiency, reduce the storage time of materials, and increase the production efficiency. The facility layout planning of manufacturing enterprises is one of the most critical and difficult points in the manufacturing industry.

At present, intelligent manufacturing is pushed by the general trend of events. The fore-end manufacturing factories have begun to build intelligent factories as their development goals. For the planning and construction of intelligent factory, the key step is how to make efficient use of workshop through reasonable facility layout. This paper analyzes the common problems in the facility layout problems of factories, studies the relevant solutions, and puts forwards suggestions on the layout of smart factories, in order to provide good references for facility layout to manufacturing enterprises.

2. Common Problems of Facility Layout in Factories

Facility is an important element in the factory, which can refer to equipment, land, building, utility etc. For manufacturing enterprises, production logistics is the flow of production materials between production equipment. At the planning level, the layout of the facilities is optimized according to the logistics situation, which is conductive to the enterprise to plan production logistics from the perspective of logistics strategy and improve the compatibility of production logistics system to reduce the logistics costs and improve logistics efficiency. Facility layout refers to the problem that the various manufacturing resources, such as processing equipment, auxiliary equipment, material handling equipment and aisles, in the production process, arrange reasonably in the workshop according to certain principles and constraints, so that the production coordination relationship of the system is optimized for example the material handling cost is minimum. Facility layout problem directly affects

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all logistics activities including raw material entry, storage, handling, and processing in the production process of the factory, which is a problem that all manufacturing enterprises need to face when optimizing production logistics.

The main goal of facility layout planning and design is to make the personnel, materials, funds and information in the enterprise reach the most reasonable, economic and efficient arrangement in the process of flow, which can be summarized as follows: (1) Meet the requirements of process flow. As far as possible to make the flow of production objects convenient and fast resulting in the minimum investment in equipment and the shortest cycle in production. (2) Use space efficiently. All available space resources should be mobilized as much as possible for the production process, so as to avoid the extra idle cost caused by the idle space. (3) Save the cost of logistics handling. It can facilitate the material handling, shorten the handling distance, reduce the intensity of handling activities, and avoid the complex and heavy transportation as much as possible. (4) Keep the flexibility of production and arrangement. Adapt to the changing product demand, process and equipment constantly updated and expand the demand for productivity. (5) Adapt to the rationality of enterprise structure and convenient management. Let closely related processes or areas be arranged nearby, or even combined. (6) Provide convenient, safe and comfortable working environment for employees.

In practice, due to the lack of sufficient attention, unreasonable planning methods, short of designers or other factors, there are the following common problems in the facility layout of factories.

The first is inefficient handling process and ineffective handling flow. In the production process, the operation process is cumbersome and complex. Because of the unreasonable layout planning, the repeated handling rate of logistics in the workshop is very high, and the long-distance handling is caused. According to the statistics, about 70% of the process is invalid handling, which greatly increases the operating costs of enterprises.

Secondly, due to the lack of good production logistics layout planning. Raw materials, work in process and finished products are often overstocked, which brings great pressure to the limited space of factory buildings and warehouses. The overstocking of raw materials and products increases the capital cost of enterprises, and the overstocking of work in process will occupy the limited space of production workshop, while the accumulation of finished products will make the products unsalable, which makes enterprises face huge market risk.

Thirdly, many installed equipment cannot be fully utilized for the lack of equipment management. Because of continuous improvement of the production process, some equipment has become idle, while some of them is not enough. These will bring a lot of problems to the facility layout of the factory, which should be considered comprehensively before the facility layout planning.

In addition, for the manufacturing enterprises, the site refers to the production workshop. Many production workshops generally have the bustle without plan or purpose on site. It seems to be very busy on the surface, in fact they are in a hurry. Many useless work that doesn’t produce any benefit. Long-term blind work makes the low efficiency of the factory production.

3. Facility Layout Problem and Solutions

The layout design of the factory requires all departments in the factory, including the location and transport route of each operation unit, such as the mutual location of production workshop, auxilliary production workshop, warehouse, office. At the same time, design the process, internal and external connection, transport mode. The design of workshop layout should not only solve the location layout of production equipment, autxilary service department, storage facilities and other equipement, but also consider the material handling process and transport mode.

According to the classification of workflow, facility layout can be divided into process principle layout, product principle layout, group principle layout, positioning principle layout and flexible principle layout. When the process principle is arranged, the equipment with the same function and similar value are concentrated in the same workshop, which makes the production and transport more conveniently. Each operation is carried out by suitable machinery and equipment, which can be applied to the production of many varieties and small batch. Product principle layout is a process of arranging production step by step according to the production process. It is generally applied to small varieties and large quantities of products, and is also one of the most commonly used forms in manufacturing enterprises. Group principle layout is also called unit layout, which integrates parts with similar shape or production process, and integrates different facilities to form a facility group for overall processing

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and production. Because the product volume is too large, and they are not easy and suitable to handle for the traditional workflow, the positioning principle layout is the local processing and installation. Flexible principle layout is market-oriented, operators and machines are rapidly changing according to the different requirements of customers in the market. It requires that the whole layout can quickly change from one product to another. This kind of production line layout is difficult, especially suitable for personalized customized production. In addition, according to the system function, it can be divided into storage layout, sales layout, and project layout. Storage layout referes to arrange the layout of warehouse to the compents, that plays a role of storage function rather production function. In sales layout, the benifit of sales is only considered. Project layout is the one-time sorting of components with fixed equipemnt, which changes with the process of the project.

3.1. SLP Method

In the 1960s, Richard Mather, combined with his years of enterprise experience, proposed a method of facility layout planning, system layout planning (SLP). This planning method is a systematic design method, accepted by many enterprises, which has played a great role in promoting the development of facility planning [2].

Applying SLP method to arrange the system, the data preparation of research objective should be processed firstly to analyze the basic elements, including products (P), quantity and output (Q), routing (R), auxilliary service (S) and production schedule timing (T). Through analysis of the relationship between logisitics and non-logistics between departments, the comprehensive correlation table of departments is drawn. Then substitue in the actual area on each department and fit the departments into the available space to dra space relationship diagram. Finally, other existing constrians are employed to cut down number of feasible solutions, resulting in a small set of solutions. The layout, scheme evaluation and selection are completed.

3.2. Block Layout

Block layout was first proposed by Koopmans and Beckmann in 1957 [3]. Generally speaking, block layout is modeled as a quadratic assignment problem (QAP), that is, only some interrelated equipment is arranged to candidate positions and one department can be set in one location instead of considering the shape, size and orientation of equipement. QAP is also one of the NP-hard combinatorial opitimization problems with optimal challenges in recent years. The model of QAP is described as follows : let the total number of facilities in the production system be n, the set of all facilities is $E=\{ei|i=1,2,\ldots,n\}$. Let m be the number of positions where the facility can be planced into the production system ($m \geq n$), then the position set is $P=\{Pj \mid j=1,2,\ldots,m\}$, the set of all possible arrangements S= ExP. Let C (s) be the material handling cost of any layout scheme. C (s) is a function related to the material flow between facilities and the material handling cost. The goal of layout design is to find a layout scheme $s^* \in s$, so that the layout cost is $C^* = \min (C(s)) = C(s^*)$.

In the QAP model, it is assumed that the number of facilities is equal to the number of locations in the layout space, but this is not always the case in practice. When the number of facilities is less than the number of locations, the number of facilities can be equal to the number of locations by introducing empty facilities, so that the system can be modeled by quadratic allocation model. When the number fo facilities is greater than the number of locations, the spatial layout problem is not established again, and the facilities need to be transferred to a larger space for layout. In the facility layout problem of production line, when the number of equipment is small, the mathematical modeling of facility layout of production line, it can be easily completed by using the quadratic allocation model, so it is widely used in practice. In addition to the quadratic assignment model, other modeling methods for block layout problems include quadratic set covering model, linear integer programming model, mixed integer programming model, graph theory model, etc. These layout models can be transformed into QAP model through corresponding changes [4].

3.3. Detailed Layout

When considering the shape, size and other information of facilities, it is the problem of detailed layout. The result of the detailed layout problem is the coordinates and orientation of each facility in the workshop. The modeling of the detailed layout problem is more complex than the block layout problem, since the optimization objectives and constraints are more.

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The optimization objective of the detailed layout problem is the key of the whole layout problem. It requires the whole layout process and becomes the evaluation index of the layout scheme. In practical problems, different detailed layout problems have different optimization objectives, which are generally extracted from some principles of layout design experts. In the aspect of logistics design, all kinds of facility should be arranged according to the actual process route and production process, so as to facilitate the operation of workers and reduce the material return rate. At the same time, according to the material flow and logistics route, make the logistics meet the needs of the production process, to achieve the minimum material handling costs. Besides logistics, it should also pay attention to the arrangement of personnel flow and handling mode. In terms of plant building, make full use of the workshop area, shorten the material transportation, and carefully arrange the entrances and exits, passageways, etc. Taking into account the net spacing between the equipment and the workshop wall, the facility should be arranged as neatly as possible to avoid loose or tight arrangement. In addition to the equipment itself, there must be sufficient personnel to operate, pass and maintain the required location. There must be room for stacking raw materials, semi-finished products, finished products and packaging materials, as well as necessary transport channels. In addition, it should meet the requirements of special facility placement, and necessary to consider the non-logistics factors for system layout, which should be convenient for management. At the same time, it is necessary to consider the function, production nature, safety, environmental protection, health, fire prevention, transportation, equipment installation and maintenance requirements of each operation unit, so as to provide convenient, safe and comfortable operation and working environment for employees [5].

From the above basic principles of equipment layout, detailed facility layout is a multi-objective optimization problem with qualitative and quantitative objectives. In the quantitative aspect, the equipment layout mainly considers maximizing material transfer efficiency, space utilization, utilization of workers; minimizing production time, investment cost and work in process inventory. In the qualitative aspect, the relationship between facilities should be considered, such as adjacency, aesthetics, comfort of operation, safety of production, convenience of monitoring, flexibility, customization of products, simplification of manufacturing system, balance of equipment processing capacity and so on. The quantitative objective of facility layout can be obtained directly or by establishing a model and calculating through a certain solution method. When the optimization algorithm is used to solve the facility layout problem, the quantitative objective is taken as the main optimization objective of facility layout. Qualitative objective is difficult to quantify by numerical value, and its design mainly depends on experience and lacks evaluation criteria, so it is usually considered as the suboptimal objective of facility layout or the evaluation factor of layout scheme. After the completion of the layout optimization algorithm, the qualitative objectives can be optimized through simulation or visual observation in virtual reality technology or through human-computer interaction.

4. Suggestions of Facility Layout in Factories

The links of manufacturing industry are complex and diversified, which depend on the joint effort of multiple production department. The results of each production department are integrated to get the final product. Each production department has its own specific tasks and responsibilities, when implementing their own tasks, the cooperation with other departments is also considered. Only through efficient cooperation qualified products can be produced efficiently and effectively. In the view of the existing problems in the facility layout of factories, the following suggestions are put forward.

The facility layout should first meet the requirements of process flow and process conditions. Designers should fully understand the functional principle and structure of the product, go deep into the production site, and fully understand the existing production conditions and process flow. Only with a detailed understanding of production process, designers can keep the route smooth, continuous and fast in the layout process, and avoid the repeated road crossing as far as possible.

Designers should make use of the principles and methods of the layout of various facilities and combine with the actual situation to make a reasonable layout. The workshop layout described above includes product principle layout, process principle layout, group principle layout, positioning principle layout and flexible principle layout. The layout of production line includes straight line, S-line, T-line, U-line and O-line. Designers can choose different layout methods according to the actual situation. There are many factors involved in the layout of facilities. In the actual planning, it is necessary to conduct a full investigation of the problem, establish a theoretical mathematical model and use the computer to solve it, which can help to find the best solution of layout.

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In the layout planning of facilities, the safety principles of earthquake prevention and fire prevention should be met. In the workshop of dangerous work, it should reserve the response tools to deal with emergencies, and reserve the fire and explosion-proof area. For the workshop of precision work, it should do a good job in shockproof treatment. In addition, noise is harmful to the environment, so in the layout of the workshop to consider the treatment of noise prevention. Production will generate harmful gasses, bad smell, dust, waste residue, which will affect the health of workers, In the process of layout, pollution sources should be avoided as far as possible.

In a word, the principle of shortest distance, smooth logistics, and reduction of inventory, easy communication, safety and flexible mobility should be followed in the layout of facilities. The connection between the upper and lower processes should be in line with the shortest moving distance of people, facilities and materials, so as to reduce the handling in the process of operation. The flow of human, machinery and materials is reasonable and smooth, and the process switching is fast. The purpose of reducing inventory is to balance the product flow and make the materials in the work unit run more quickly. It is convenient to transmit all kinds of information needed for production. Consider the easy operation of operators and the safety of personnel, equipment, auxiliary tools and products. Production increase, variety change and other operations should be flexible.

5. Conclusion

In the production process of the factory, it spends most of the time on the loading and unloading, handling, packaging, distribution and other logistics activities. The reasonable logistics system facility layout design is one of the most effective methods to improve the overall production efficiency of facoties. This paper first puts forward the common problems of the layout of factory facilities, and gives some suggestions on the layout of factory facilities through the research on the layout and methods of facilities for the reference of enterprises.

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