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Research on Layout Optimization of J Company's Grain and Oil Processing Workshop

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Abstract: Whether the workshop layout is reasonable has a significant impact on logistics efficiency, production costs, and production efficiency. This article takes the grain and oil processing workshop of Company J as the research object and conducts a field investigation of its grain and oil processing workshop using the SLP (System Layout Design) method. Based on the logistics volume of the production site and the correlation of each functional area, the correlation analysis is carried out from two aspects: logistics factors and non-logistics factors. The interrelationship diagram of the operation units in the workshop, the ranking of the comprehensive proximity of the operation units, and the location correlation diagram of the operation units were obtained, and the improvement plan was designed based on the principle of route optimization layout. Through the optimized design, transportation efficiency was enhanced, workshop area utilization was improved, production costs were reduced, and good social and economic benefits were created for the enterprise. It can also provide a reference for similar enterprises to carry out related work.

Keywords: SLP; Workshop layout; Facilities layout; Optimization

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1. Introduction

In today's rapidly developing world economy, manufacturing, as a pillar of the national economy, is the core driving force for the sustained growth of the national economy. In the increasingly fierce market competition, the enhancement of an enterprise's competitiveness not only depends on the strengthening of sales capabilities and the guarantee of product quality, but more crucially, on improving production efficiency and shortening the production and sales cycle of products [1, 2]. However, the on-site management practices of many manufacturing enterprises have exposed numerous problems, which have restricted their development potential. A typical phenomenon is that enterprises lack scientific facility layout planning in the initial construction stage and often rely on empiricism for equipment arrangement. With the continuous increase in order volume, this unscientific layout has directly led to a series of problems, such as chaotic material accumulation in the workshop, unnecessary repetition in the production process, and mutual interference among people, machines, and materials. Eventually, it has caused a continuous decline in production efficiency and severely restricted the further development of the enterprise [3, 4].

In response to the above-mentioned predicament, the system layout design method offers a scientific solution. As a classic and important production facility planning method, the core of SLP lies in systematically analyzing the production process and logistics volume, constructing the interrelationship diagram among various operation units, and based on this, rationally arranging the operation unit areas within the workshop [5]. This method can effectively address the logistics congestion and efficiency bottlenecks caused by unreasonable layout, thereby ensuring the smooth progress of the production process and ultimately achieving the goal of optimizing the entire production system and enhancing the comprehensive competitiveness of the enterprise [6]. This paper uses the SLP method to analyze the layout of the grain and oil processing workshop of Company J, scientifically and reasonably arranges the workshop facilities, forms a reasonable logistics system, improves the efficiency of logistics operation, reduces the operating costs of the enterprise, achieves the optimization of the logistics efficiency and production costs of the production system, and thereby enhances the market competitiveness of the enterprise.

2. Layout of grain and oil processing workshops and production processes

J's grain and oil processing workshop is divided into multiple Spaces: preform injection molding workshop, cap injection molding workshop, pre-treatment room, pre-processing blending workshop, oil pressing workshop, filling workshop, water treatment area, dry package storage area, high-pressure air compressor room, reception room, transformer and distribution room, etc. J's grain and oil processing workshop is on the second floor and has one oil press production line, four filling and packaging lines, and three carton packaging lines. The raw materials enter the production workshop from the South, the produced products enter the filling line, the filling line is placed East-West, the preforms, caps and other packaging materials enter the filling and packaging line for sealing, then enter the carton packaging line for packing, the cartons are sealed, labeled and processed, and the finished products are conveyed into the temporary storage area on the first floor and then transported by forklifts to the workshop finished goods warehouse on the first floor. Outbound is completed on the right side of the first floor of the company according to the order. To describe the current layout of the workshop more clearly, the specific layout of the second floor is drawn as shown in **Figure 1**, and the correspondence between the numbers in the figure and the specific areas is shown in **Table 1**.

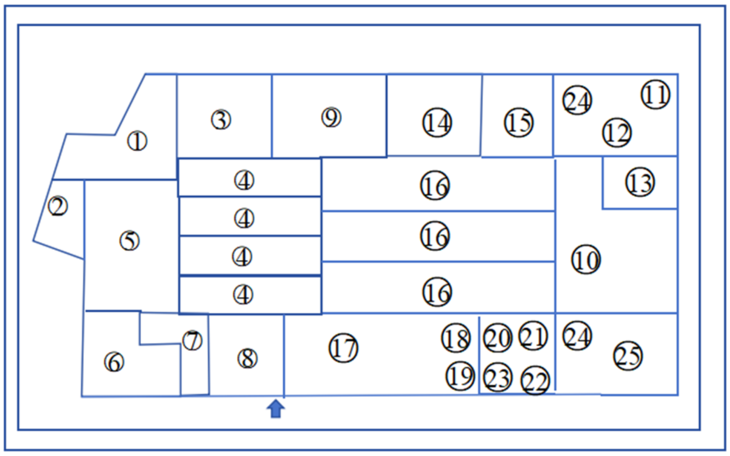

Figure 1. Original layout of the processing workshop

Table 1. Correspondence table of workshop area numbers

Numbers	Area division	Number	Area division
1	Transformer and distribution room	14	Carton label library
2	High-pressure air compressor room	15	Bottle cap warehouse
3	Preform injection molding workshop	16	Carton packaging line
4	Filling line	17	Water treatment area
5	Dry package storage area	18	Water treatment control room
6	Oil press line	19	Water treatment chemicals room
7	Preparation area before processing	20	Conference room
8	Pre-treatment room	21	Production office
9	Cap injection molding workshop	22	Reception room
10	Teleportation line	23	Fire Control Room
11	Driver’s lounge	24	Toilet
12	Print room	25	Restaurant
13	Entry point		

3. Analysis of enterprise facility layout based on SLP

3.1. Logistics analysis

Based on the data of the logistics handling distance and material handling volume between each operation unit within the workshop, the logistics intensity between each operation unit pair was obtained by multiplying the logistics handling distance between each operation unit pair by the corresponding material handling volume. To more intuitively represent the logistics intensity between pairs of operation units within the workshop, A five-level classification system is introduced, using the letters A, E, I, O, and U to represent the five logistics intensity levels from high to low, respectively [7]. These grades are based on a careful assessment of the relative proportion of logistics intensity in total logistics routes and volumes.

Based on the resulting logistics intensity and logistics intensity grades, list the logistics intensity between pairs of operation units by numerical magnitude, and then classify the intensity grades according to intensity grade proportions. **Figure 2** shows a logistics interrelationship diagram for a more intuitive comparison of logistics intensities between different operation units.

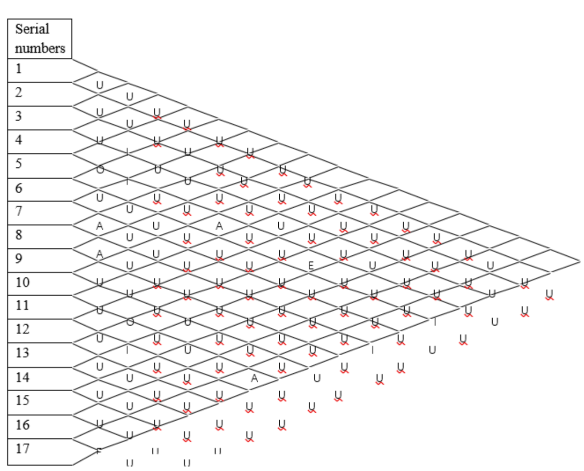

Figure 2. Diagram of logistics interrelationships

Observing the above figure, it can be seen that the pairs of operation units belonging to Grade A ultra-high logistics intensity are 9–15, 8–7, 4–9; There are 6–7, 14–15, 4–12 units that belong to the E category of extremely high logistics intensity. The other six pairs of operation units have a wide range or average level of logistics intensity, respectively, and there are also pairs of operation units with extremely low logistics intensity that can almost be ignored. These pairs of operation units have almost no direct logistics relationship, but each has its own role in the production process. Therefore, non-logistics relationship analysis is also required during layout optimization. To achieve the desired layout effect.

3.2. Analysis of interrelationships among job units

When determining the relationships among various work units, it is necessary to take into account both logistics and non-logistics relationships to form a comprehensive consideration system to obtain comprehensive relationships, and to achieve a reasonable layout based on these relationships [8]. The following will discuss how to accurately define relationships by setting weight ratios and quantifying calculations.

(1) Set the weight ratio

In the actual production process, the relative importance of non-logistics relations and logistics relations often varies depending on the specific demands and conditions of the workshop. In order to accurately reflect the different effects of these two relationships on workshop layout optimization, it is necessary to set appropriate weighting ratios to determine their importance. Generally speaking, the weighting ratio should be between 1:3 and 3:1. For processing workshops, where the logistics factor has a greater impact than the non-logistics factor, set the weighting value of the logistics and non-logistics interrelationship among each operation unit in the workshop to m:n=2:1 [9].

(2) Quantification calculation

Specifically, quantitative calculations use the following assignment criteria: A=4 (for very strong relationships), E=3 (for strong relationships), I=2 (for general relationships), O=1 (for weaker relationships), U=0 (for no direct relationship), X=-1 (for conflicting or negative relationships). Let the quantified value of the logistics relationship level for any two job units be M, the quantified value of the non-logistics relationship level be N, and the comprehensive relationship closeness value be Z; and the formula for calculating the comprehensive relationship closeness value Z is $Z=m*M+n*N$ [10]. At the same time, the quantified value of the comprehensive interrelationship is calculated based on the division ratio of the comprehensive interrelationship grades among the operation units as shown in **Table 2**.

Table 2. Calculation table of comprehensive relationships among work units

Serial Numbers	Job unit pairs	Logistics relationship weighting: 2		Non-logistics relationship weighting: 1		Comprehensive relationship	
		Grade	Quantified values	Grade	Quantified values	Quantified value	Grade
1	1–2	U	0	I	2	2	O
2	1–13	U	0	X	-1	-1	X
3	1–17	U	0	X	-1	-1	X
4	2–13	U	0	X	-1	-1	X
5	2–17	U	0	X	-1	-1	X
6	3–4	U	0	O	1	1	O

Table 3 (Continued)

Serial Numbers	Job unit pairs	Logistics relationship weighting: 2		Non-logistics relationship weighting: 1		Comprehensive relationship	
		Grade	Quantified values	Grade	Quantified values	Quantified value	Grade
7	3–5	I	2	E	3	7	E
8	3–6	U	0	O	1	1	O
9	3–10	U	0	O	1	1	O
10	3–13	U	0	X	-1	-1	X
11	3–17	U	0	X	-1	-1	X
12	4–5	O	1	E	3	5	I
13	4–6	I	2	A	4	8	E
14	4–7	U	0	O	1	1	O
15	4–8	U	0	O	1	1	O
16	4–9	A	4	A	4	12	A
17	4–10	U	0	O	1	1	O
18	4–12	E	3	E	3	9	E
19	4–13	U	0	X	-1	-1	X
20	4–16	I	2	U	0	4	I
21	4–17	U	0	X	-1	-1	X
22	5–6	U	0	I	2	2	O
23	5–9	U	0	O	1	1	O
24	5–10	U	0	O	1	1	O
25	5–12	U	0	O	1	1	O
26	6–7	E	3	A	4	10	A
27	6–8	U	0	I	2	2	O
28	6–9	U	0	O	1	1	O
29	6–10	U	0	O	1	1	O
30	6–12	U	0	O	1	1	O
31	6–16	O	1	E	3	5	I
32	7–8	A	4	A	4	12	A
33	7–16	U	0	I	2	2	O
34	8–13	U	0	X	-1	-1	X
35	8–16	U	0	I	2	2	O
36	8–17	U	0	X	-1	-1	X
37	9–11	O	1	E	3	5	I
38	9–14	U	0	O	1	1	O
39	9–15	A	4	A	4	12	A
40	10–12	I	2	I	2	6	I

Table 3 (Continued)

Serial Numbers	Job unit pairs	Logistics relationship weighting: 2		Non-logistics relationship weighting: 1		Comprehensive relationship	
		Grade	Quantified values	Grade	Quantified values	Quantified value	Grade
41	10–13	U	0	X	-1	-1	X
42	10–17	U	0	X	-1	-1	X
43	11–14	U	0	O	1	1	O
44	13–14	U	0	I	2	2	O
45	14–15	E	3	E	3	9	E
46	16–17	U	0	X	-1	-1	X

3.3. A comprehensive classification based on closeness of relationship

As can be seen from **Table 2** above, the combined quantified values among the pairs of operation units range from -1 to 12, reflecting the combined closeness of different pairs of operation units in terms of logistics and non-logistics relations. By sorting the results of the comprehensive quantified values in the table from largest to smallest, the proportion of each quantified value range can be obtained, providing data support for the optimization of the workshop layout, and a more scientific and reasonable layout plan can be formulated based on the quantified analysis results. Compared with the data analysis in **Table 3**, the proportion of the comprehensive interrelationship grades occupied by the operation units conforms to the conventional proportion, so no further adjustment is needed.

Table 3. Classification of the degree of closeness of comprehensive interrelationships

Combined quantified values	Grade	Job unit pairs number	Proportion of job unit pairs
10–12	A	4	2.94%
7–9	E	4	2.94%
4–6	I	5	3.68%
1–2	O	20	14.71%
0	U	90	66.18%
-1	X	13	9.56%
Total	-	136	100.00%

4. SLP-based workshop layout optimization

4.1. Workshop layout optimization scheme design

After a detailed analysis of the interrelationships among the operation units, in order to more precisely guide the layout of the operation unit area and thereby determine the initial SLP optimization plan, the next step is to sort the operation units based on the comprehensive quantified values in **Table 3** mentioned earlier. This step is crucial for ensuring efficient collaboration among operation units, reducing logistics costs, and enhancing productivity, as shown in **Table 4**.

Table 4. Comprehensive proximity ranking table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1		1											-1				-1
2	1												-1				-1
3				1	3	1				1			-1				-1
4			1		2	3	1	1	4	1		3	-1			2	-1
5			3	2		1			1	1		1					
6			1	3	1		4	1	1	1		1				2	
7				1		4		4								1	
8				1		1	4						-1			4	-1
9				4	1	1					2			1	4		
10			1	1	1	1						2	-1				-1
11									2					1			
12				3	1	1				2							
13	-1	-1	-1	-1				-1		-1				1			
14									1		1		1		3		
15									4					3			
16				2		2	1	4									-1
17	-1	-1	-1	-1				-1		-1						-1	
The total	-1	-1	4	16	9	15	10	8	13	4	3	7	-5	6	7	8	-7
Sorting	14	15	12	1	5	2	4	6	3	11	13	9	16	10	8	7	17

Referring to the legend in **Table 5**, further transform **Table 3** into a visualized job unit position correlation diagram. The proximity between job unit pairs is represented as shown in **Table 6**, with different numbers and shapes of lines connecting each other. Job unit pairs with a comprehensive relationship level of grade A are represented by 4 lines, grade E by 3 lines, and so on. Draw the job unit position correlation diagram as shown in **Figure 3**. [11].

Table 5. Symbols for the nature of work of job units

Serial numbers	Name	Legend	Notes
1	Operations	○	A variety of machining processes in workshop production
2	Temporary storage	◇	Temporary inventory of semi-finished and finished products
3	Auxiliary	⊃	Assist the workshop to operate normally
4	Storage	▽	Regular inventory of production objects at the storage location

Table 6. Examples related to the location of work units

Quantitative value	Grade	Number of lines	The degree of closeness of the hierarchy
4	A	4 Straight lines	Absolutely necessary to get close
3	E	Three straight lines	Particularly important Approach
2	I	Two straight lines	Important
1	O	1 straight line	General
0	U	-	Not important
-1	X	1 curve	Don't want to get close

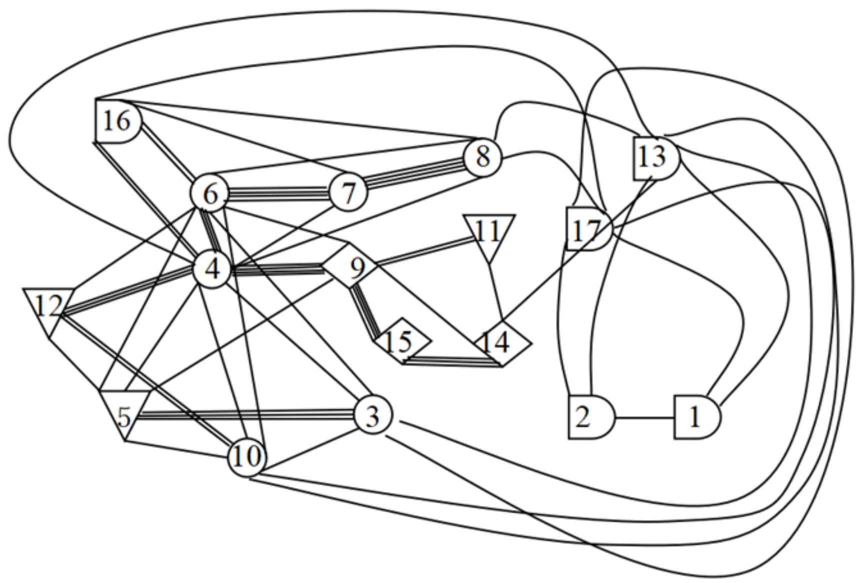

Figure 3. Job unit location-related map

Distribute the job units from center to edge according to their scores as shown in **Table 4**. The A-level job units with the highest scores and the strongest closeness will be placed in the center position, and since they are the closest to other units, only one distance unit interval is needed; Work units with slightly lower scores but still higher levels of closeness will be placed on the periphery of Class A units to ensure a certain degree of independence while maintaining close ties; U-level work units can be placed freely, as long as there is no obstruction; X-class job units should be placed as far apart as possible.

The proximity of each operation unit can be roughly understood from the above text. Then, in combination with the production situation of the workshop that has been statistically analyzed, make reasonable adjustments to each operation unit and draw the initial workshop layout optimization plan based on the SLP method according to a certain proportion, as shown in **Figure 4** below [12].

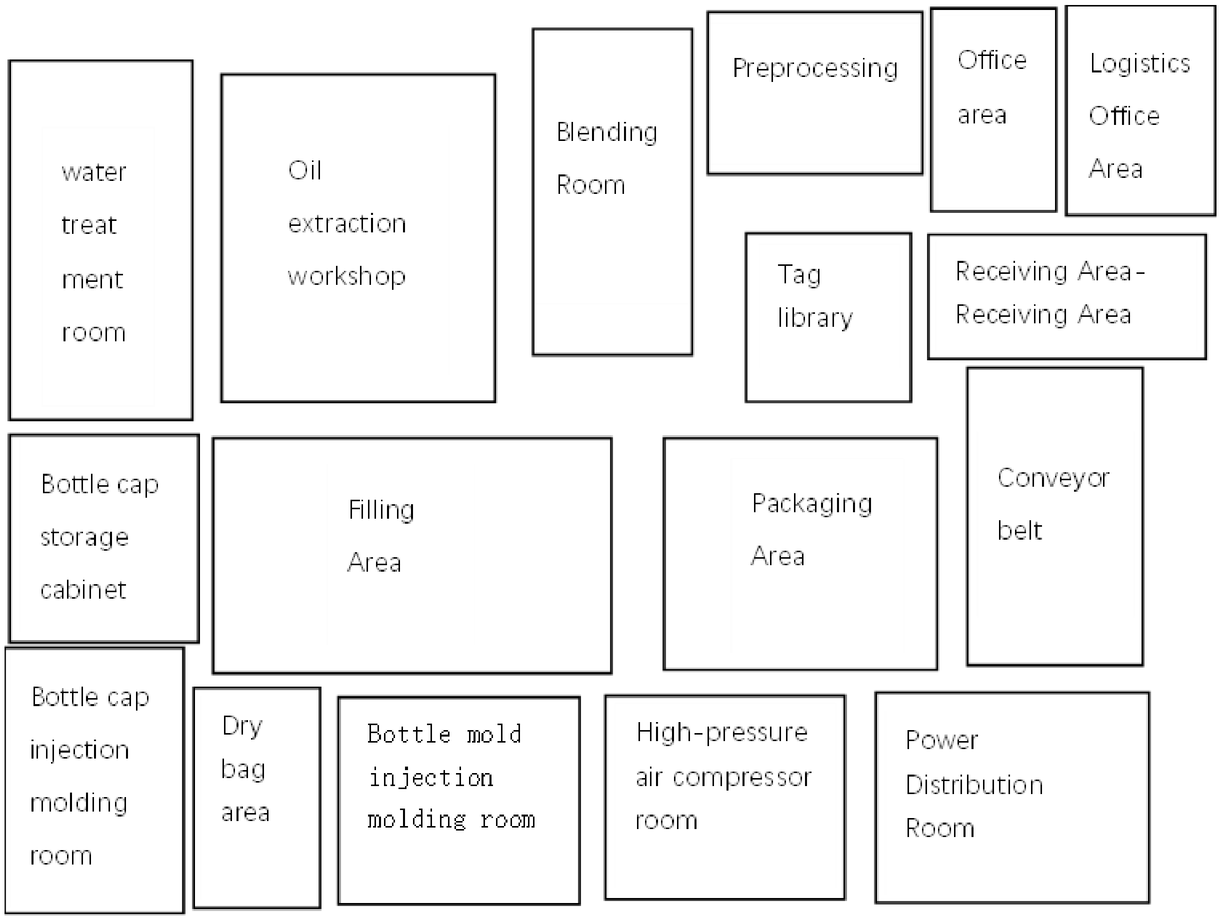

Figure 4. Initial optimized layout of the workshop

4.2. Scheme evaluation

In response to the problems with the existing layout mentioned earlier, an evaluation of the optimized plan is presented.

(1) The workshop layout is more in line with production requirements

The optimized plan takes into full account the continuity of the processing workshop workflow, the centralization of management and supervision, and the core principle of "people-oriented" in the application of the SLP method, comprehensively considering the working environment, health and safety of employees. While pursuing production efficiency and economic benefits, particular attention is paid to potential hazards such as noise, vibration and chemicals that may cause harm to employees' health. In the optimized layout, water treatment rooms that could be harmful to people are placed on the edge away from office workers and visitors who lack professional protection; At the same time, the new layout also places more dangerous distribution rooms at the edge, away from operation units such as dry packaging and filling areas where the situation could be exacerbated in the event of a fire or explosion.

(2) The distance for material handling is effectively shortened

In the original layout, there were overly long logistics routes such as from the cap warehouse to the filling room and from the oil press line to the water treatment room, which are also the key parts that need to be addressed in this optimization using the SLP method. Based on the straight-line distances between the centers of each operation unit, the final optimized logistics handling distance of the workshop operation unit is 285, which is 23.18% lower than the original plan. It can be seen that the optimized plan is better than the original plan, indicating that there are significant problems with the original layout.

(3) The intensity of logistics was effectively reduced

Under the condition that the original volume of logistics remains unchanged, the logistics distance is shortened, and the logistics intensity is significantly improved. After optimizing the logistics process, the logistics intensity has been successfully reduced from 13,568 to 12,116. This significant change indicates that the optimized plan has achieved a marked improvement in logistics efficiency. Specifically, the logistics intensity was reduced by 1452, or 10.7%, which visually demonstrates the positive effect of the optimized plan in reducing logistics transportation costs and improving logistics operation efficiency.

(4) Easier to manage

Compared with the original layout, the optimized layout makes the work units with similar functions more concentrated and thus easier to manage. First, the centralized layout makes material management more efficient. In a relatively centrally managed warehouse, the storage, allocation, and search of materials can all be done in a relatively small area, which significantly reduces the time and cost of personnel movement and material handling. At the same time, centralized management also helps to reduce warehouse space and the need for special handling, further improving the efficiency of material management, allowing enterprises to better control and optimize inventory and reduce costs resulting from inventory loss and expiration. Secondly, the centralized layout also helps with personnel management. In workshops with the same functions, personnel are responsible for roughly the same content, and the relatively centralized layout can enhance communication among employees, command issuance by upper-level managers, and training effectiveness. Finally, the centralized layout also helps to enhance the safety of equipment. By strengthening security management of the same equipment, centralized layout can reduce the risk of theft, and also help to identify and address potential security hazards in a timely manner, facilitating regular management of equipment and subsequent equipment replacement.

5. Conclusion

This paper uses the SLP method to conduct a facility planning analysis of the J company workshop, divides the production units, and on the basis of analyzing the logistics and non-logistics relationships within the workshop, ultimately determines the comprehensive relationship levels of the operation intervals and proposes practical solutions. Through optimization, the logistics routes between processes avoided intersections, thereby significantly reducing the logistics intensity, minimizing material detours, lowering the labor intensity of workers, improving the working environment, and enhancing the utilization efficiency of the factory.

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