Optimization Study of the Production Layout in the Trouser Workshop of GR Company

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Abstract: GR Company, as a traditional clothing manufacturing enterprise, the suit trousers production workshop has the problems of irrational facility arrangement, poor space utilization leading to long material handling routes, inconvenient employee pick-up and space wastage. Considering the current development, this paper, based on SLP theory, draws a comprehensive relationship map of operations by collating and analyzing the interrelationships between logistics and non-logistics of the production process and operation units, and then re-plans and designs the workshop in a reasonable way. The results show that: the location of the operating units is drawn out, combined with the actual demand for the area of each operating unit, the preliminary design of the two layout schemes; the weighted factor method and scoring method are used to select the optimal layout of the more reasonable scheme 1. From the total logistics intensity, logistics handling distance, handling costs, the reasonableness of the scheme 1 is verified. The distance of material handling is shortened between the various operating units to reduce the cost, improve the production efficiency and space. Optimizing the layout of workshop facilities is of great significance in improving the operating efficiency of the production system and controlling the cost, so as to enhance the competitiveness and sustainable development of the enterprise.

Keywords: Production Workshop; SLP; Layout Optimization; Operation Flow Chart

1. Introduction

The textile and garment industry is an important part of China's national economy and is an industry with great potential for development. Data analyses and field research have shown that high internal handling costs, low productivity and chaotic transport conditions in the workshop pose serious constraints to enterprise development.In order to increase competitiveness and risk resistance, enterprises must reduce internal handling costs and improve production efficiency, the most important of which is to optimise workshop layout.[1,2] Good workshop layout can make the logistics transport distance shorten to the maximum, save logistics costs, improve production efficiency; at the same time, the workshop production process and procedures for comprehensive consideration, so that equipment, space, energy and manpower to achieve the most effective optimisation.[3,4]

In terms of workshop layout design, the theory of Systematic Layout Planning (SLP) has been relatively mature and widely used.[5–8] SLP analyses the interrelationship between logistics and non-logistics of production process and operation units, draws out the comprehensive relationship map of operation, and then makes reasonable planning for production layout to achieve the purpose of optimizing the whole production system.

Based on the SLP theory, this paper re-plans and designs the trousers workshop rationally and proposes an optimisation and improvement plan to cope with the problems of irrational arrangement of facilities and poor space utilisation in the trousers workshop of GR Company, which lead to long material handling routes, chaotic transportation and reduced production efficiency.

2. Workshop Layout

2.1 Overview of Workshop Layout

Layout of production workshop facilities refers to a series of activities to achieve the specific functions and tasks of the workshop by arranging the mutual location and area between each production unit and auxiliary facilities within the workshop, and the production equipment within the workshop, in accordance with certain principles.[9]

Workshop layout optimisation can reduce transport time and cost and effectively improve production efficiency. Optimised layout can place similar operations or continuous processes in adjacent workstations, ensure that the workshop with frequent production operations contact material transport distance is minimised, eliminate unnecessary waste of capacity, and make rational use of space.

2.2 System Layout Design Method (SLP)

The SLP method is widely used in the layout of various manufacturing sites. In 1961, Richard Muther firstly put forward the theory of system planning and layout, which fully combines the analysis of logistic relationship between operating units and the analysis of the degree of closeness.[10]

In the workshop layout, firstly, according to the production process and material flow of the product to draw the logistics from to table to determine the logistics intensity level between the operating units; according to the personnel contact and other interrelationships outside the logistics factors, to analyse the non-logistics relationship between the operating units. Secondly, based on the layout of the production plant is affected by different degrees of logistics and non-logistics factors, so set the corresponding influence coefficients and weighted calculation of logistics and non-logistics relationships, collated and analysed to get the comprehensive relationship between the operating units of the degree of proximity and the comprehensive relationship table. Then, according to the comprehensive degree of proximity, determine the layout of the central location, from the layout of the centre of the layout of the operating units, the layout of each operating unit, substituting the actual footprint of each operating area, in accordance with the appropriate proportion of the reduction combined with the location of the operation of the relevant map, the formulation of each operating unit of the workshop layout of the preliminary optimization plan. The implementation steps are shown in Figure 1.[11–14]

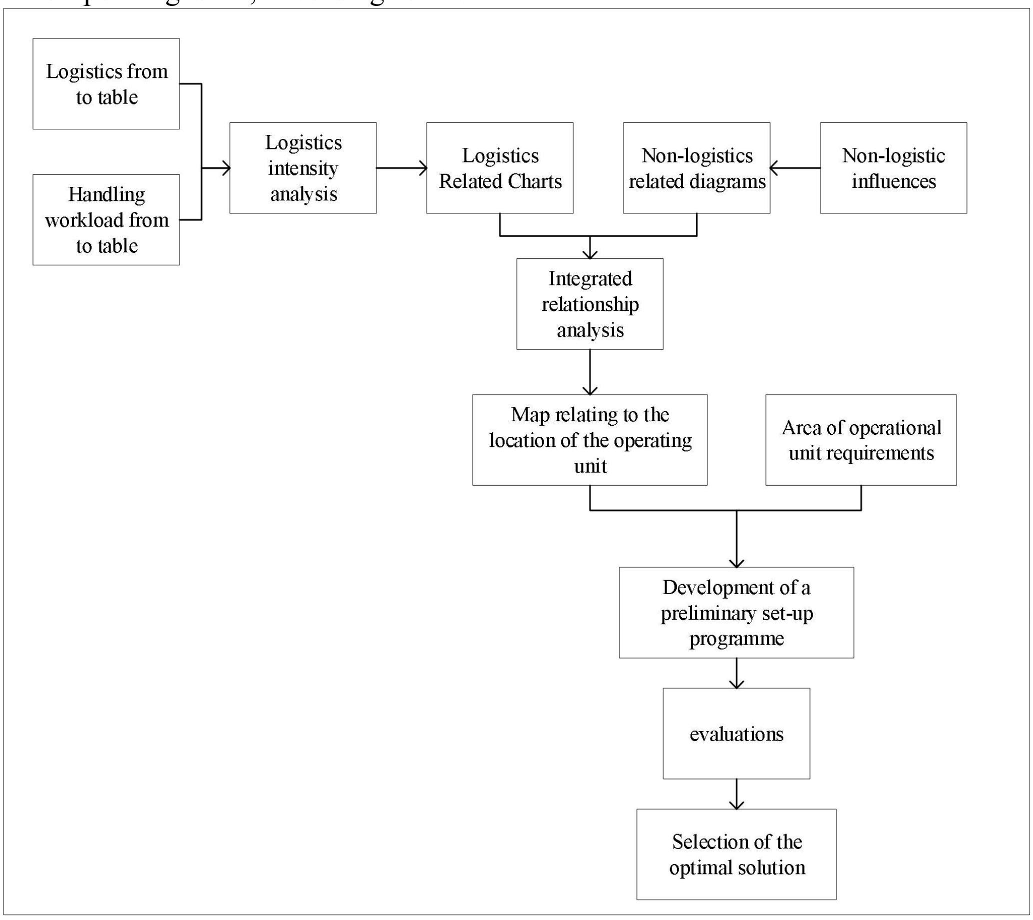

Figure 1. SLP Implementation Steps

3. The Current Situation and Problems of Trousers Production Workshop Layout

3.1 Western Trousers Workshop Layout Status Quo

GR's trousers production workshop has a floor area of 1,260 square metres. The workshop currently has two trousers production lines, both of which can be operated at the same time. According to the production process, the trousers workshop is divided into eight working areas, namely fabric warehouse, cutting area, ironing area, sewing area, quality inspection area, packaging area, finished products area and office. The left side of the workshop entrance is the fabric warehouse, which is used to pile up the cloth and auxiliary materials waiting to be transported to each operation area for production and processing; the right side of the workshop entrance is the finished product warehouse, which is used to pile up the trousers waiting to be transported after production; the sewing area is located in the northern part of the workshop, and the sewing process, as the most critical process in the trousers production process, is completed by five sewing groups (front piece, back piece, waist, trouser seam assembly , trouser seam and waist seam) together.The layout of the workshop is shown in Figure 2.

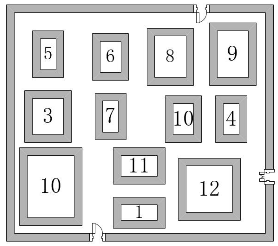

Figure 2. Initial Layout of the Workshop

The trousers production workshop mainly relies on forklift trucks to carry out material transport work in the workshop. The logistics transport route of the workshop is shown in Figure 3.

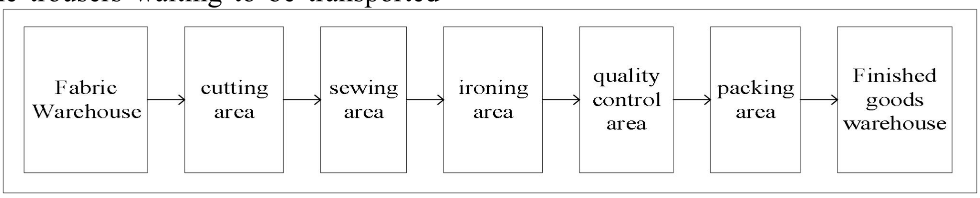

Figure 3. Logistics and Transportation Roadmap

In this process, raw materials and accessories are firstly stored in the fabric warehouse, and then transported to the cutting room for pre-processing and preprocessing. After counting the number of cut pieces and zigzagging them according to the model number, the materials are transported to the sewing area to be assigned to different working groups to officially start the sewing process of the trousers. After sewing, the trousers are transported to the ironing area for shaping, the quality inspection area for measuring and quality inspection of the ironed trousers, the packaging area for checking the composition, colour and barcode, confirming that the type and specification are correct, and then hang the label, and then according to the number of containers on the packing list, the trousers are loaded into the finished goods warehouse to be sent to the customers.

3.2 Problems with the Layout of The Trouser Workshop

Workshop layout will directly affect the material handling time and cost. If the workshop layout is not reasonably planned, the placement of production equipment is not in line with the natural order of the production process, which may lead to long material handling routes and inconvenient for employees to take materials.[14] Field research found that the production and processing area of GR's trousers workshop is mainly concentrated on one side of the workshop, and the workshop layout mainly has the following problems:

(1) Unreasonable arrangement of facilities. The fabric warehouse and cutting area, which have greater logistics intensity, have a larger handling workload, and the ironing area and quality inspection area have too long a transport distance. Material handling routes are complex, not in line with the "U-shaped", "Y-shaped" or "a" production layout, and even material reflux phenomenon, resulting in a larger total amount of personnel and material movement, increasing the logistics cost is increased and production resources are wasted.

(2) Poor space utilisation. There is too much space reserved for material flow between two

neighbouring operating units, and there are some vacant areas, resulting in wasted space.

4. Optimised Production Layout Design for Trousers Workshop

Workshop layout design should follow the following principles: ① process flow principle, that is, in line with the requirements of the trousers production process, to avoid intersecting each other and circuitous transport, to ensure that the process flow is smooth. ② Overall optimal principle. Following the principle that the overall optimal is greater than the local optimal, the units with close production and collaboration links should be arranged close to each other to maximise the use of resources. At the same time take into account the impact of the environment on people, improve employee satisfaction.

4.1 Logistics Relationship Analysis

Combining the positional coordinates of each operation unit, the distance Di (where i represents the operation unit) between each operation unit with logistics traffic in the production process of trousers is calculated on the basis of the material flow of the trousers production line in a day, and the material handling weight Wi is measured between the operation units with material transport, and the formula for calculating the amount of logistics handling between each operation unit (1) is as follows:

$$E = \sum Di \times Ei \quad (1)$$

Using the quantitative analysis attributes in the improved SLP method, A, E, I, O, U are used to represent different logistics intensity levels, where "A" refers to the highest logistics intensity, "E ~ U" refers to higher, larger, general and negligible, respectively, and the proportion of material flow is 40%, 30%, 20%, 10%, 0. The total logistics handling volume between operating unit pairs is used to represent logistics intensity, and the logistics intensity is divided according to the logistics intensity level. The proportion is 40 per cent, 30 per cent, 20 per cent, 10 per cent and 0. The total logistics handling volume between pairs of operating units is used to express the logistics intensity, which is divided according to the logistics intensity level, and the logistics intensity table between operating units is shown in Table 1.

Table 1. Logistics Intensity Analysis Table

serial number	The operating unit is responsible for	Logistics handling volume (kg-m)	hierarchy
1	2-3	600	A
2	4-10	562.5	A
3	9-4	437.5	E
4	8-9	262.5	E
5	11-12	212.5	E
6	10-11	180	I
7	3-6	175	I
8	3-5	162.5	I
9	5-8	150	O
10	6-8	150	O
11	3-7	130	O
12	7-9	125	O

According to the results shown in Table 1, the logistics relationship between the fabric warehouse and the cutting area (2-3), the ironing area and the quality control area (4-10) is the closest, with the highest logistics intensity (A). This is followed by the higher logistics intensity (E) between the trouser seam and waist seam area and the ironing area (9-4), between the trouser seam assembly area and the trouser seam and waist seam area (8-9), and between the packaging area and the finished product warehouse area (11-12). Between quality control area and packaging area (10-11), cutting area and back piece area (3-6), cutting area and front piece area (3-5) is higher logistics intensity (I), the logistics relationship between the remaining operating units is general logistics intensity (O), and the logistics intensity level between the operating units that do not have logistics relationship is U, which is not in the scope of consideration of the facility layout.The logistics correlation diagram for the 12 operating units is shown in Figure 4.

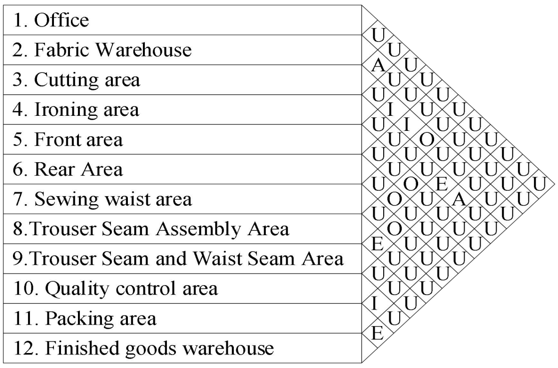

Figure 4. Logistics-Related Diagram

4.2 Analysis of Non-Logistic Relationships

The relationship between operating units is affected by many aspects, both by the logistics relationship and by non-logistics factors other than the influence of material flow. Through the research on the trousers production workshop, it was found that: the continuity of the production process, material handling, personnel contact, ease of management, frequency of operational contact and similarity of the nature of the operation are the six main factors affecting the non-logistics relationship between operating units.

The closeness between operating units is further classified into five levels, in order A, E, I, O and U.

The total number of pairs of operating units can be calculated using equation (2), where N denotes the number of operating units and P denotes the number of pairs of operating units.

$$P = N(N-1)/2 \quad (2)$$

There are a total of 12 operating units in the workshop, and the total number of interrelationships between operating pairs is 66 pairs, as shown in Table 2 for the specific non-logistics classifications.

Table 2. Non-Logistics Classification Table

hierarchy	A	E	I	O	U
densely populated	Absolutely important.	special importance	significant	usual	unimportant
Proportion %	2-5	3-10	4-15	10-25	45-80

By consulting with the management of the workshop, based on the above selection of the influencing factors of non-logistic relationships and the basis for the classification of the grades, this study analyses and summarizes the non-logistic relationships that exist between the 12 operating units, and classifies the corresponding grades based on the influencing factors of non-logistic relationships corresponding to each operating unit. As a result, the non-logistic relationship between the 12 areas in the workshop is mapped out, as shown in Figure 5.

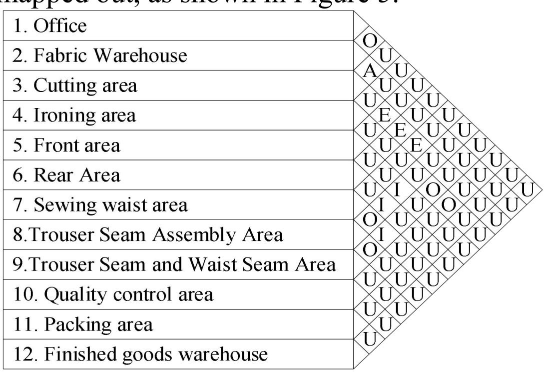

Figure 5. Non-Logistics Relationship Diagram

4.3 Integrated Relationship Analysis

Since this paper aims to improve the layout of workshop facilities to shorten the material handling distance, reduce the return flow of materials, avoid the crossing of handling routes, and improve the space utilisation rate and productivity as the main goal, the logistics relationship between operation pairs is more important, i.e. the weight of logistics relationship: non-logistics relationship = 2:1 is used to calculate the degree of the integrated relationship between the operation pairs[13] as shown in equation (3).

$$Tij = m \times Mij + n \times Nij \quad (3)$$

Where i ,j denote job pairs, and M and N denote the scores corresponding to different levels of logistics and non-logistics relationships, respectively.

Quantify the intensity level of logistic and non-logistic relationships by taking A=4, E=3, I=2, O=1 and U=0.

Combining the logistics and non-logistics relationship levels and their corresponding assignments, the integrated interrelationships between all 66 operation pairs between operation unit 1 and operation unit 12 are calculated by the ratio of weights and classified into levels, resulting in the integrated interrelationship table of the trouser production plant as shown in Table 3.

The ranks and values between the 12 job pairs in Table 3 were analysed to plot the combined relationship of the job units, as shown in Figure 6.

Table 3. Consolidated Interrelationship Table

Serial Number	The Operating Unit Is Responsible For	Degree Of Intimacy				Integrated Relationship	
		Logistics Relations (Weighted Value: 2)		Non-Logistic Relations (Weighted Value: 1)			
		Hierarchy	Mark	Hierarchy	Mark	Hierarchy	Mark
1	2-3	A	4	A	4	A	12
2	3-5	I	2	E	3	I	7
3	5-8	O	1	I	2	O	4
4	6-8	O	1	I	2	O	4
5	8-9	E	3	O	1	E	7
6	4-10	A	4	O	1	E	9
7	11-12	E	3	U	0	O	6
8	7-8	U	0	O	1	U	1
9	5-6	U	0	U	0	U	0
10	3-6	I	2	E	3	I	7
11	3-7	O	1	E	3	O	5
12	7-9	O	1	I	2	O	4
13	9-4	E	3	O	1	I	7
14	10-11	I	2	U	0	O	4
15	1-2	U	0	O	1	U	1
16	1-12	U	0	O	1	U	1

4.4 Improved Programme Design

(1) Determine the degree of integrated proximity. The greater the degree of integrated proximity, the closer to the centre, rather than away from the centre, the layout of the corresponding operational unit should be. The quantitative value corresponding to the closeness of the relationship between an operational unit and other operational units is the quantitative value of the degree of integrated proximity.[12] The 12 operational units are ranked in order of their combined proximity as follows: 3, 9, 4, 8, 2, 10, 5, 6, 7, 11, 12, 1.

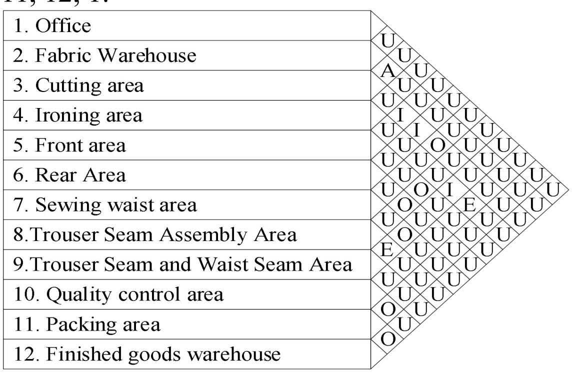

Figure 6. Integrated Relationship Diagram

(2) Plotting the location correlation of operational units. According to Table 3 and the results of the sorting of the combined proximity of the operational units, different types of lines are used to describe the interrelationships between the operational units; the greater the number, the closer the interrelationships. As shown in Figure 7.

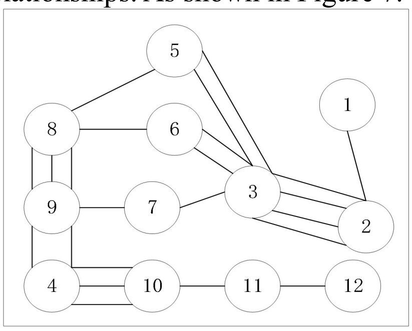

Figure 7. Map Relating to the Location of Operational Units

5. Improvement Programme Evaluation and Comparison of Results

5.1 Improved Programme Evaluation Options

After determining the approximate location of each operation area in the workshop, according to the actual demand for area by each operation unit, using Visio software for drawing, adopting standard drawing specifications and using appropriate legends and symbols, the following two plan layout schemes are preliminarily designed for the trousers production workshop. As shown in

Figures 8 and 9.

In addition to the main factors such as logistics intensity and handling distance of the layout, it is also necessary to take into account factors such as process continuity, machine utilisation rate and workshop safety environment. In the layout optimisation of the trousers production workshop, it is found through research that five factors, such as logistic operation efficiency, process continuity, machine usage rate, area utilisation rate and workshop safety environment, affect the design of the system layout scheme. After the assessment by the workshop director, department supervisor and external experts, each factor is given a weight and a grade to calculate the average of the total score, and the scores are filled in the scheme scoring table, as shown in Table 4.

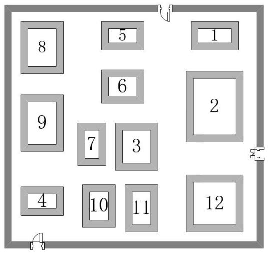

Figure 8. Optimisation Scenario I

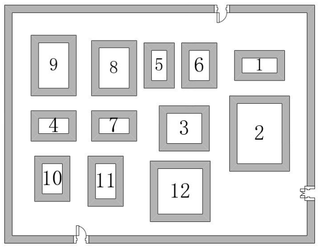

Figure 9. Optimisation Scenario Ii

Table 4. Programme Rating Scale

consideration	Evaluation level (A=4, E=3, I=2, O=1, U=0)	
	Option 1	Option 2
Efficiency of logistics operations (0.5)	A	A
Process continuity (0.4)	E	I
Machine utilisation rate (0.3)	O	I
Area utilisation (0.2)	E	E
Workshop safety environment (0.1)	I	O
score (of student's work)	4.5	4.2

The scoring results indicate that Option 1 is the optimal layout optimisation solution.

5.2 Comparison of Optimisation Effects

Whether the layout scheme is effective or not can be reflected by the size of logistics intensity. The distance of material handling between operating units is calculated according to the distance between two road centre points that are at the same level as the centre point of the operating unit, and the weight of materials handled is calculated according to the total weight of materials handled by each operating unit on a daily basis. The results of the comparison of the logistics intensity between operation units before and after optimisation are shown in Table 5.

Table 5. Comparison Table before and after Optimisation

responsibility for	Volume of material flow (kg)	pre-optimisation		post-optimisation	
		Transport distance (m)	Lifting workload (kg-m)	Transport distance (m)	Lifting workload (kg-m)
2-3	40	15	600	4.5	180
4-10	25	22.5	562.5	4.5	112.5
9-4	35	12.5	437.5	7	24.5
8-9	35	7.5	262.5	3.5	122.5
11-12	42.5	5	212.5	4.25	180.625
10-11	36	5	180	3	108
3-6	14	12.5	175	3.35	46.9
3-5	13	12.5	162.5	6.2	80.6
5-8	10	15	150	7.1	71
6-8	20	7.5	150	7.1	142
3-7	26	5	130	2	52
7-9	10	12.5	125	4	40
add up the total	306.5	132.5	3147.5	56.5	1381.125

As shown in Table 5, the total logistics intensity of trousers production workshop of GR Company is 3147.5 kg-m before optimisation, and 1381.125 kg-m after optimisation, which is 57.36% lower than that before optimisation; the transport distance is 132.5 m before optimisation, and 56.5 m after optimisation, which is 56.12% lower than that before optimisation; the workshop manager roughly gives the handling cost as 35×10 yuan/(kg) by combining electricity cost, labour cost and depreciation of equipment. The transport distance of pre-optimization layout scheme is 132.5m, and the transport distance of post-optimization layout scheme 1 is 56.5m, which is 56.12% reduction in transport distance; the workshop manager roughly gives the handling cost as 35×10-3 yuan/(kg-m) by integrating electricity cost, labour cost, depreciation of equipment, etc., and calculates the handling cost of pre-optimization layout scheme as 110.16 yuan, and the handling cost of scheme 1 as 48.34 yuan.

6. Conclusion

This paper takes the trousers production workshop of GR Company as an example, firstly, it gives a brief overview of the workshop layout and system layout design (SLP), clarifies the implementation steps of SLP, analyses the current situation of the facility layout of the trousers production workshop in the light of the actual situation of the workshop and finds out the existent problems; it applies SLP to optimise the overall layout of the workshop and analyses the logistic and non-logistic relationships between the various operating units in the trousers production workshop, The overall layout of the workshop is optimized by SLP method, which analyzes the logistic relationship, non-logistic relationship, non-logistic relationship, and location of the operating units and the operation area of the workshop, and initially formulates the optimization scheme for the layout of two kinds of workshop facilities. Finally, from three aspects of total logistics intensity and handling distance and cost, the layout scheme of trousers production workshop before and after optimisation is compared and analysed, and the reasonableness of scheme one is verified.

The workshop has been optimised to shorten the material handling distance between the operating units, reduce material detours, reduce costs, and then improve production efficiency and space utilisation, improve the working environment of employees, and the layout is in line with the lean production concept. Optimising the layout of workshop facilities is of great significance in improving the operational efficiency of the production system and controlling the cost, so as to enhance the competitiveness and sustainable development of the enterprise.

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