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Research on Layout Optimization of Auto Seat Assembly Workshop based on SLP

Kaixin Zhao*

School of Management, Shandong University of Technology, Zibo 255049, Shandong, China

***Corresponding author:** Kaixin Zhao, zkx1101924@126.com

Abstract: With the continuous advancement of intelligent manufacturing, the focus of enterprises in the production process has gradually shifted to the direction of more intelligent and automated. Under this background, each company gradually carries on the intelligent transformation and upgrading of the workshop, and the layout planning of the workshop facilities is an important step. Reasonable workshop layout is helpful to improve the handling efficiency of workshop materials and reduce workshop cost effectively. By analyzing the current situation and existing problems of the facility layout of a car seat assembly workshop, the SLP method is used to optimize the overall layout of the workshop, and the effect of the proposed optimization scheme is verified to be effective.

Keywords: Workshop layout; SLP method; Intelligent manufacturing

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1. Introduction

With the "Industry 4.0" and "Made in China 2025" strategy, China has set off a new wave of revolution in the manufacturing industry, and the automobile manufacturing industry has also developed rapidly and changed, which puts forward higher requirements for the production and operation of automobile enterprises. In this context, most of the automobile manufacturing enterprises have been transformed and upgraded, and the production system of enterprises is becoming more and more important. As the core of the enterprise production system, the layout design of the workshop is particularly important. Workshop layout is one of the most considered, complex, and core issues in manufacturing system design, and its main idea is how to effectively organize and arrange various manufacturing resources to achieve optimal design objectives in a given environment [1]. A good workshop layout can ensure product quality while minimizing production costs, making the production process continuous and reducing annual cost savings by 10%–30% [2]. It can be seen that a reasonable workshop layout is of great significance for improving logistics efficiency, reducing production costs, and enhancing the competitiveness of enterprises [3].

Systematic Layout Planning (SLP), as an important method in the study of workshop layout, has been widely used in domestic and foreign research. Through continuous analysis and summary of workshop layout problems, scholars around the world have made the content of workshop layout research more accurate, systematic, and constantly refined. Based on the SLP method, Ji et al. successfully realized the dynamic planning and layout of the site by dividing the construction phase and classifying the state of the site [4]. Khariwal et al. adopted the SLP method to carry out layout optimization design of enterprise logistics parks, which further improved the rationality of relevant layout planning [5]. Gao improved the SLP method and applied it to the layout transformation project of the company's production workshop to verify the effectiveness of the layout transformation scheme [6]. Wang et al. analyzed and improved the layout of the production workshop of a steel structure company by using the SLP theory, which ultimately reduced material redirection, reduced handling time, improved production efficiency, and ensured production safety [7]. Haryanto et al. designed the optimal location of each unit structure of the logistics center in combination with SLP to solve the positioning problem of the structural units and proposed the facility layout scheme of each unit to carry out effective production activities [8].

To sum up, scholars have conducted a lot of research and practice on layout optimization problems in various fields by using the SLP method, but through combing literature, it is found that the SLP method is rarely applied in the layout of car seat manufacturing workshops. Given this, this paper selects a seat assembly workshop of an automobile company as the research object. By analyzing the current layout of the workshop and existing problems, the SLP facility layout planning method is adopted to optimize the layout of the workshop, providing a reference scheme for the improvement of the workshop layout.

2. Current situation of car seat assembly workshop

The automobile company selected in this paper is the leading automobile seat supplier in China, which is committed to the design, research, and development of automobile seats. The company's car seat assembly workshop is set up in a huge rectangular factory, the main operating units include a raw material area, a skeleton preassembly area, a plastic ironing area, a plastic parts installation area, a functional check area, a finished product staging area, etc. The layout diagram of the workshop at this stage is shown in **Figure 1**.

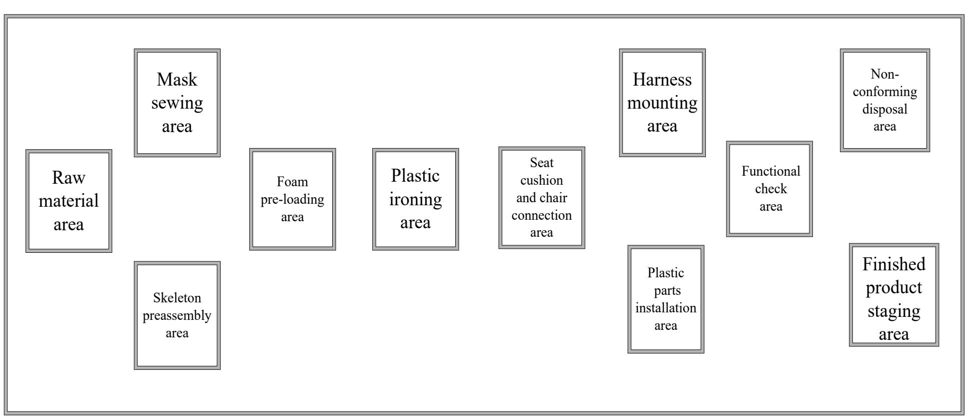

Figure 1. Initial workshop facility layout

Given the main research on the layout of the car seat assembly workshop, the whole chair process of the car seat assembly workshop is analyzed, which aims to provide a reliable basis for the subsequent layout of the workshop facilities. In the seat assembly process, the quality inspection of the product and the transportation of various materials is essential, so the assembly process also includes inspection engineering. The specific workshop process flow is shown in **Figure 2**.

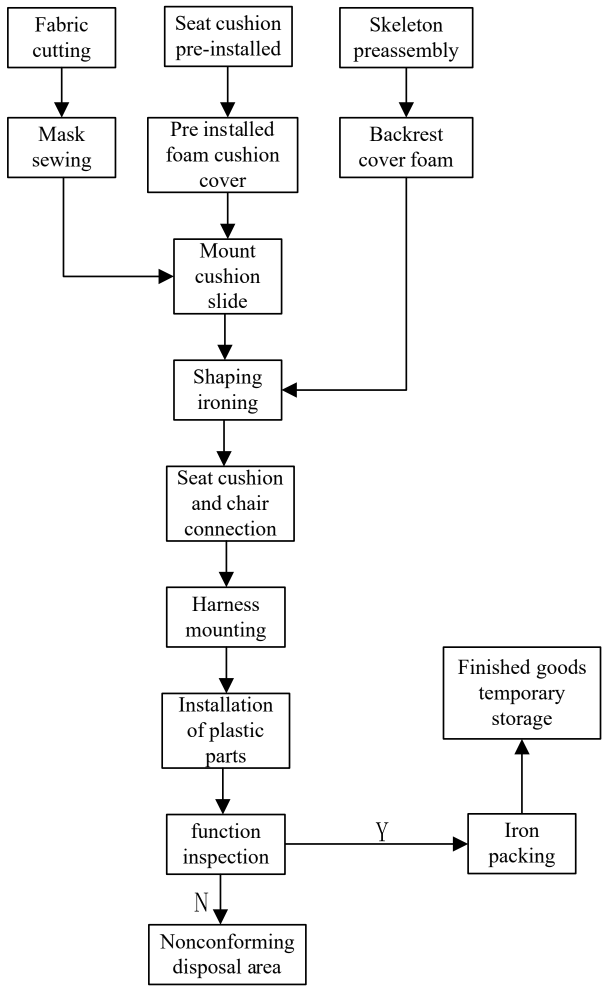

Figure 2. Process flow diagram

3. Problems and analysis of car seat assembly workshop

To fully understand the main problems existing in the layout of the assembly workshop, this paper analyzes and studies the current workshop from the perspective of F-D quantitative analysis. In the process of car seat assembly, many process links cannot be concentrated in the same position, so the scope of operation of the workshop needs to be divided, as shown in **Table 1**.

Table 1. Summary of workshop units

Serial number	Operating unit	Feature	Area (m^2)
1	Raw material area	Incoming inspection, temporary storage of raw materials	15*35
2	Mask sewing area	Cover material production	18*30
3	Skeleton preassembly	Backrest, cushion skeleton preassembly	18*30

Table 1 (Continued)

Serial number	Operating unit	Feature	Area (m^2)
4	Foam re-loading area	Foam cover connection, installation bayonet, etc.	15*35
5	Plastic ironing area	Back shaping, guide sleeve ironing, etc.	15*35
6	Seat cushion and chair connection area	Back seat cushion connection, seat belt installation, etc.	15*35
7	Harness mounting	Airbag, heating module wiring harness installation, etc.	18*30
8	Plastic parts installation area	Switch button, support wire installation	18*30
9	Functional check area	Functional and visual inspection	15*35
10	Finished product staging area	Storage of finished products	24*30
11	Non-conforming disposal area	Temporarily store non-conforming products	24*30

D analysis is a quantitative logistics analysis method. Firstly, the material handling paths of different operating units in the car seat assembly workshop were determined, as shown in **Figure 3**. It can be seen that the layout of the workshop still has the problem of unreasonable arrangement of facilities, such as the cross confusion of material handling routes and the distance gap between raw materials and various operating units, which makes the assembly process appear discontinuous phenomenon, resulting in certain losses in time and cost.

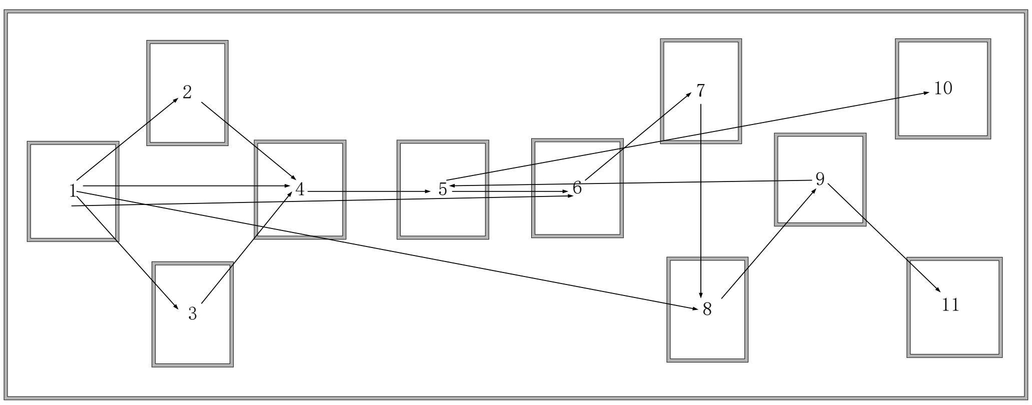

Figure 3. Material handling road map

By using European distance to calculate the distance relationship between various operating units, and applying statistics to the average material flow of each operating unit in the workshop, the workshop F–D diagram is drawn by calculating the material flow relationship and distance relationship between various operating units in the assembly process of car seats in the assembly workshop. The material flow (F) is the vertical axis and the distance (D) is the horizontal axis (**Figure 4**).

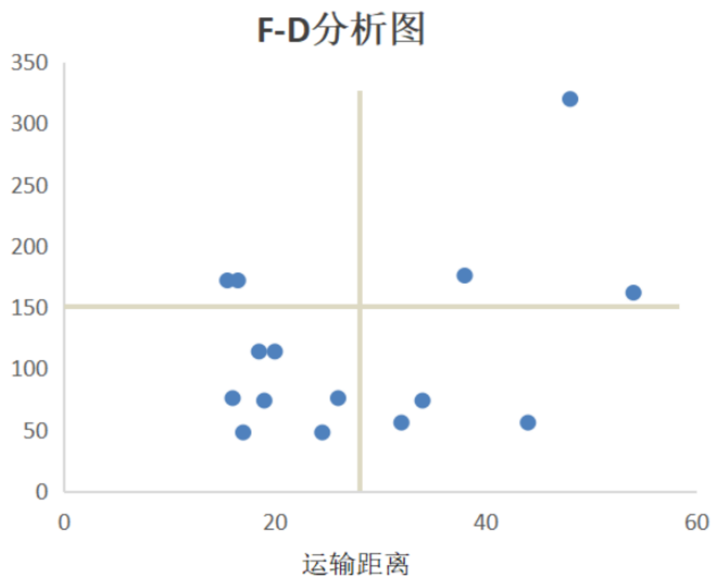

Figure 4. F–D analysis chart

In the Cartesian coordinate system, the workshop operation units are divided into four regions: A represents the workshop operation units with large logistics volume but close handling distance; B represents the workshop operation unit with large logistics volume and transportation distance, which is the area that needs the most improvement; C represents workshop operation units with small logistics volume and close transportation distance. This area is an ideal layout for workshop equipment operation units, which is in line with reality; D represents workshop operation units with a small logistics volume but a long transportation distance and the transportation distance needs to be shortened in this area. When planning the layout, it is necessary to consider the characteristics and impacts of different areas, and reasonably arrange high material flow and long-distance workshop operation units.

From the above, it can be seen that there are still problems with the layout of the car seat assembly workshop, such as insufficient scientific division of operating units and repeated handling between operating units. In addition, through research, we found that the workshop did not take into account the adverse effects of machine noise on human health when arranging the layout. Therefore, it is necessary to optimize the layout of the car seat assembly workshop to improve workshop efficiency.

4. Layout optimization of car seat assembly workshop based on SLP

The design of the workshop layout using the SLP method generally involves the analysis of logistics relationships, non-logistics relationships, and comprehensive relationships among various operating units [9]. The current situation of the workshop layout can be understood through the above content, and the relationship between operating units can be further analyzed through these materials. The optimization scheme of the workshop layout based on SLP is obtained.

4.1. Logistics relationship analysis

In the process of logistics relationship analysis, five symbols A, E, I, O, and U are usually used to divide the intensity of logistics data between workshop equipment, and the intensity of logistics decreases from A to U in turn. The specific representative meanings and symbols of different levels are shown in **Table 2**.

Table 2. Classification of logistics intensity

Rank symbol	Logistics intensity	Volume ratio	Proportion of logistics routes
A	Ultra	40%	10%
E	high	30%	20%
I	larger	20%	30%
O	normal	10%	40%
U	negligible	—	—

There are 15 job pairs in the production workshop with logistics relationships. Based on the distance, material flow, and material handling path between each job unit, the volume distance product between each job pair with the logistics relationship is further calculated [10]. This data can be used to represent the logistics intensity relationship between each job pair. The logistics intensity of the workshop is sorted from large to small, and the logistics intensity of the workshop and its level are summarized according to the logistics intensity level in **Table 2**, as shown in **Table 3**.

Table 3. Summary of logistics intensity of each operation unit

Serial number	Work unit pair	distance	Logistics quantity	Logistics intensity	Logistics intensity level
1	5-10	66	1000	66000	A
2	9-5	48	1000	48000	A
3	8-9	24	1160	27800	A
4	4-5	18	1300	23400	E
5	1-8	84	240	20160	E
6	6-7	21	786	16560	E
7	1-6	66	220	14520	E
8	5-6	18	720	12960	I
9	7-8	30	410	12300	I
10	3-4	21	490	10290	I
11	1-2	21	480	10080	I
12	1-3	24	400	9600	O
13	2-4	18	486	8748	O
14	1-4	30	290	8700	O
15	9-11	24	270	6480	O

According to the summary table of logistics intensity, the logistics relationship diagram of the workshop can be obtained, which makes the logistics relationship between each operation unit more intuitive. For workshop equipment without a material handling relationship, the logistics intensity will be treated in accordance with the U level. The specific physical relationship is shown in **Figure 5**.

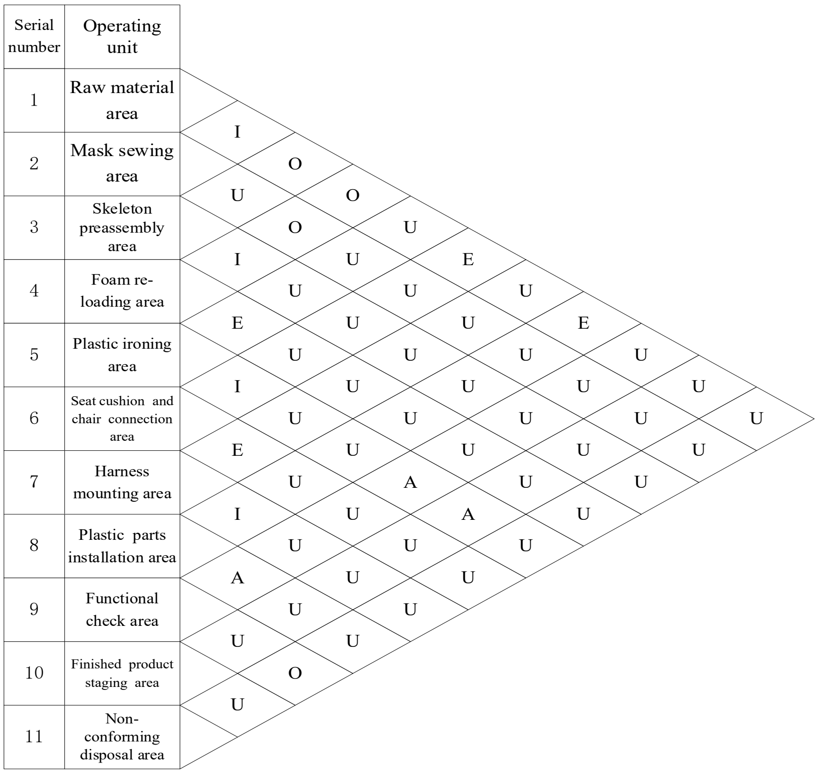

Figure 5. Logistics relationship diagram

4.2. Analysis of non-logistics relations

In addition to the analysis of logistics relations, the analysis of non-logistics relations is equally important. In the layout of the workshop, based on the actual investigation of the workshop and communication with the workshop staff, combined with the product process, the following determinants of non-logistic interaction were sorted out from different angles, as shown in **Table 4**.

Table 4. Determinants of non-logistics interrelationships

Serial number	Determining factor
1	Continuity of the production process
2	Material handling strength
3	Frequency of information exchange
4	Safe operating environment

According to the determinants of the closeness of workshop non-logistics relationship, the non-logistics relationship of workshop operation units is judged one by one, as shown in Table 5. The non-logistics relationship diagram is shown in **Figure 6**.

Table 5. Non-logistics relationship level table for each homework unit

Rank symbol	Homework unit	Relationship determinant
A	8-9, 4-5, 9-11	1,2,3,4
E	3-4, 2-4, 6-7, 5-6, 7-8	1,2,4
I	5-10, 9-5, 1-8, 1-6, 1-2, 1-3, 1-4	1,2,3
O	9-10, 2-3, 10-11, 1-5	3,4
U	……	Closeness does not matter

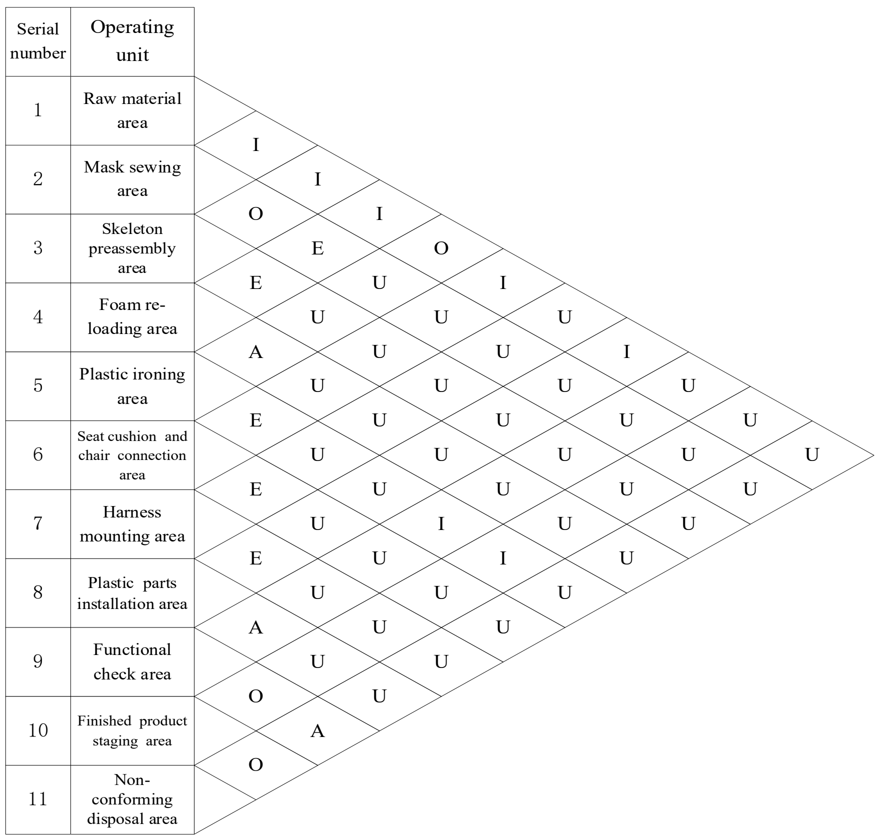

Figure 6. Non-logistics interrelationship diagram

4.3. Comprehensive correlation analysis

According to the actual situation of the automobile seat assembly workshop, the impact of logistics relations and non-logistics relations on the layout of the workshop is considered. To reduce the logistics crossover phenomenon of the workshop and the material handling cost, the logistics factors of the workshop should be taken into account when calculating the comprehensive relationship between various operating units. Therefore, the weight ratio of logistics relations and non-logistics relations in this paper is determined to be 2:1. To carry out a comprehensive correlation analysis, it is necessary to quantify the levels of logistics relations and non-logistics relations. Generally, A=4, E=3, I=2, O=1, U=0, and X=-1 are assigned to the relationship levels. The calculated comprehensive relationship analysis table is shown in **Table 6**, and the comprehensive relationship diagram is shown in **Figure 7**.

Table 6. Comprehensive relationship closeness table

Serial number	Job pair	Logistics relationship		Non-logistics relationship		Comprehensive relationship	
		Grade	Quantizer	Grade	Quantizer	Quantizer	Grade
1	8-9	A	4	A	4	12	A
2	5-10	A	4	I	2	10	A
3	9-5	A	4	I	2	10	A
4	4-5	E	3	A	4	10	A
5	6-7	E	3	E	3	9	E
6	1-8	E	3	I	2	8	E
7	1-6	E	3	I	2	8	E
8	5-6	I	2	E	3	7	E
9	7-8	I	2	E	3	7	E
10	3-4	I	2	E	3	7	E
11	9-11	O	1	A	4	6	I
12	1-2	I	2	I	2	6	I
13	1-3	O	1	I	2	4	I
14	2-4	O	1	I	2	4	I
15	1-4	O	1	I	2	4	I
16	9-10	U	0	O	1	1	O
17	2-3	U	0	O	1	1	O
18	10-11	U	0	O	1	1	O
19	1-5	U	0	O	1	1	O

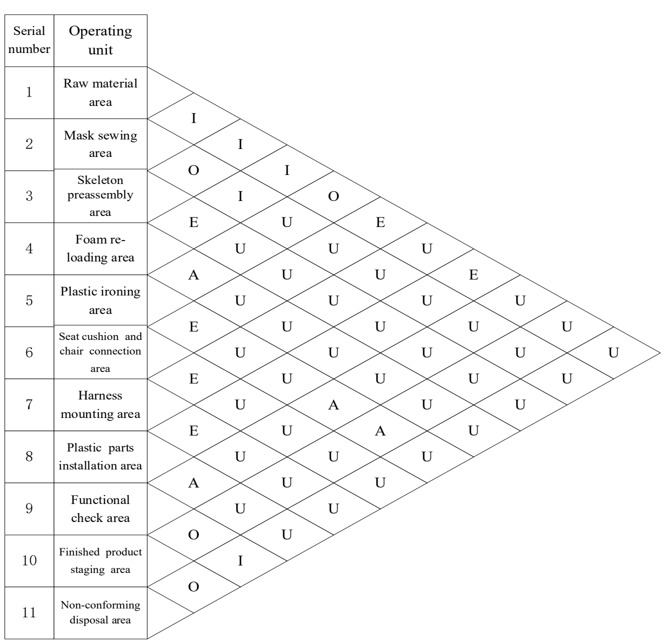

Figure 7. Comprehensive correlation diagram

5. Determine the workshop layout optimization scheme

5.1. Drawing up the workshop layout

When the SLP method is used to optimize the layout of the workshop, to further accurately derive the relative position of each work unit area in the workshop, the comprehensive quantization value between each work unit should be sorted to calculate the comprehensive proximity between the work units [11]. The quantized value of comprehensive proximity determines the position of the corresponding work unit in the layout planning of the whole workshop facility. The larger the value, the closer to the center layout. On the contrary, the smaller the value, the more it should be away from the central arrangement. Details are shown in **Table 7**.

Then draw a correlation chart of the position of the working area according to the above table, and use legend symbols to arrange their relative positions, usually using a "triangle" to represent the inventory area and a "circle" to represent the processing area. The proximity between operating units is usually indicated by a different number of solid lines, and the more the number, the closer the arrangement should be. An absolute necessity, special importance, importance, and general closeness are indicated by four, three, two, and one solid line, respectively. The location correlation diagram of the specific workshop operation area is shown in **Figure 8**. Among them, class A is 1 distance unit with the strongest degree of closeness, so it is preferentially placed; Class E is 2 distance units, the closeness is inferior to A, and the placement order is located after A; Level I consists of 3 distance units, placed after E; Level O is 4 distance units, placed after I; There is no close relationship between U-level operating units and can be placed at will.

Table 7. Comprehensive relationship closeness table

Activity	1	2	3	4	5	6	7	8	9	10	11
1		I/2	I/2	I/2	O/1	E/3	U/0	E/3	U/0	U/0	U/0
2	I/2		O/1	I/2	U/0	U/0	U/0	U/0	U/0	U/0	U/0
3	I/2	O/1		E/3	U/0	U/0	U/0	U/0	U/0	U/0	U/0
4	I/2	I/2	E/3		A/4	U/0	U/0	U/0	U/0	U/0	U/0
5	O/1	U/0	U/0	A/4		E/3	U/0	U/0	A/4	A/4	U/0
6	E/3	U/0	U/0	U/0	E/3		E/3	U/0	U/0	U/0	U/0
7	U/0	U/0	U/0	U/0	U/0	E/3		I/2	U/0	U/0	U/0
8	E/3	U/0	U/0	U/0	U/0	U/0	I/2		A/4	U/0	U/0
9	U/0	U/0	U/0	U/0	A/4	U/0	U/0	A/4		O/1	I/2
10	U/0	U/0	U/0	U/0	A/4	U/0	U/0	U/0	O/1		O/1
11	U/0	U/0	U/0	U/0	U/0	U/0	U/0	U/0	I/2	O/1	
Comprehensive degree	13	5	6	11	16	9	5	9	10	6	3
sort	2	9	8	3	1	5	10	6	4	7	11

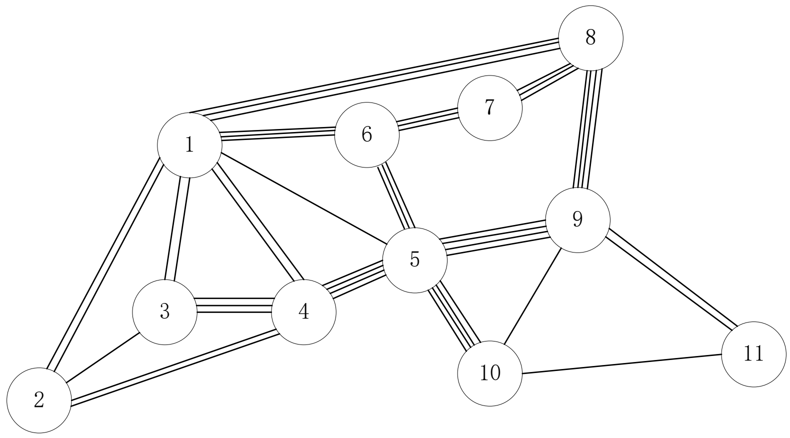

Figure 8. Location-related diagram of the workshop operation area

The diagram reflects the closeness of the working units in the workshop, but this is only the relative position of the working units under ideal circumstances. Combined with the actual situation, considering the actual constraints such as the actual reserved workshop channels, and keeping the rectangular working area distribution of the workshop as neat as possible, the initial layout optimization plan of the workshop was developed after repeated correction and adjustment, as shown in **Figure 9**.

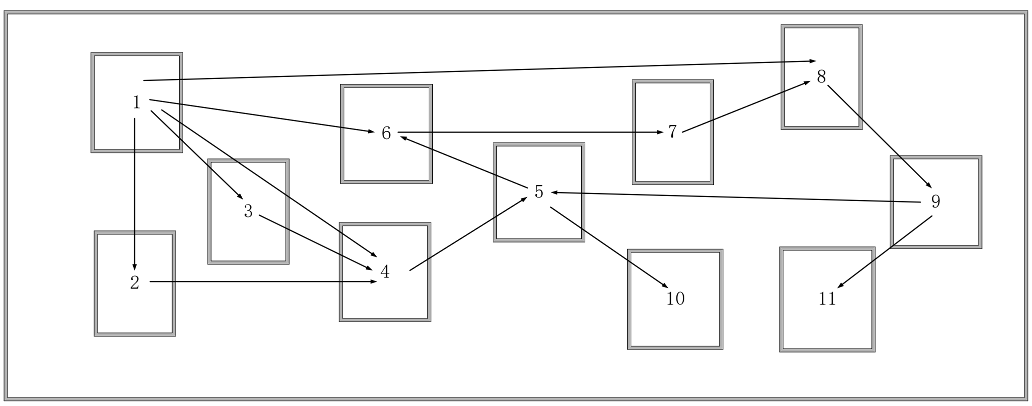

Figure 9. Workshop layout after SLP optimization

5.2. Optimization layout effect analysis

The optimized layout scheme of the workshop obtained by SLP can obtain the change of distance between each operation position of the workshop and the change of total logistics intensity, as shown in **Table 8**.

Table 8. Comparison and changes of various homework units

Serial number	Job pair	Distance	Optimized distance	Total logistics intensity	Optimized total logistics intensity
1	5-10	66	21	66000	21000
2	9-5	48	51	48000	51000
3	8-9	24	21	27800	24360
4	4-5	18	21	23400	27300

Table 8 (Continued)

Serial number	Job pair	Distance	Optimized distance	Total logistics intensity	Optimized total logistics intensity
5	6-7	84	36	20160	8640
6	1-8	21	87	16560	68382
7	1-6	66	33	14520	7260
8	5-6	18	21	12960	15120
9	7-8	30	21	12300	8610
10	3-4	21	18	10290	8820
11	1-2	21	24	10080	11520
12	1-3	24	18	9600	7200
13	2-4	18	33	8748	16038
14	1-4	30	42	8700	12180
15	9-11	24	18	6480	4860
Total		513	465	329982	292290

Through the data, the study can find that the total distance has decreased by 9.3% from 513 to 489, and the total logistics intensity has changed from 295598 to 292290. Moreover, through the comparison of the layout diagram before and after the workshop layout optimization, it can be seen that the crossing of material handling routes has been effectively reduced. It can be seen that the optimized workshop layout can effectively shorten the material handling distance, reduce the material handling intensity, reduce the handling waste, and improve the assembly efficiency of the workshop to a certain extent [12].

6. Conclusion

This paper takes the seat assembly workshop of an automobile enterprise as the research object. Through the F-D analysis of the layout status of the workshop, it is found that the layout of the workshop still has some problems, such as unscientific division of working units, repeated handling of materials, and crossing of lines. To solve the above problems, the SLP method was selected to optimize the overall layout of the workshop, and the effect of the workshop layout optimization scheme was analyzed from the three aspects of logistics handling distance, logistics intensity, and handling route, and the feasibility of the production line layout optimization scheme was verified.

Disclosure statement

The author declares no conflict of interest.

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