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AN IMPROVED SLP METHOD: LAYOUT OPTIMIZATION BASED ON MEAT PRODUCT WORKSHOP

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Abstract. *The rationality of workshop layout directly affects production efficiency, logistics intensity, production cost and so on. After adding time and main product factors to the analysis factors of the traditional SLP method, F-D method is used for problem analysis. This improved SLP method is suitable for enterprises that focus on production timeliness, especially for meat product enterprises that focus on just in time. Taking the meat product workshop of R Company as an example, the improved SLP method is used to analyze the correlation between logistics factors and nonlogistics factors based on the logistics volume at the production site and the correlation among operating units, and to optimize the original layout. The research results showed that the improved SLP method was in line with the characteristics of meat product workshop and effectively reduced the material flow.*

Keywords: Improved SLP method, Workshop layout, Meat product, Production efficiency

1. **Introduction.** At present, most production enterprises have some problems in site management. The issue of layout optimization has not been taken seriously at the workshop construction [1,2]. With the increase of orders, problems such as misplacing materials and crossing human logistics appear in the limited space of workshop, which restricts the development of enterprises. Domestic and foreign scholars have carried out a lot of research on systematic layout planning (SLP) through the analysis of production process and material flow to optimize the layout of workshop. Richard first proposed SLP method in 1961, and proposed the importance of "machine" and "material" [3]. Because of its scientific rationality, the method has been applied in various fields. Behin proposed using the SLP method to optimize the layout of a tooling manufacturer. It reduced the delivery cycle of the product by 16.66%∼33% [4]. Rodriguez and De Oliveira proposed using the SLP method to develop an optimization plan, and the optimal layout reduced the transportation distance of the production line by 29% [5]. SLP method is also applicable to the layout optimization of food processing and manufacturing industry. In recent years, food processing and manufacturing has played a very important role in the national economy [6], and the output value in each country often accounts for 15%∼18% of the total national industrial value. The food processing rate in developed countries is above 70%, or even as high as 92%, and in developing countries it is 20%∼30%. The compound annual growth rate of the global processed food market is 2.4% (2023-2028). In the food processing and manufacturing industry, meat production is the most important component, since meat products in people's lives have more and more heavy proportion. Enterprises want to improve production efficiency, and to reduce production costs. We must improve the management level of the enterprise site.

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At present, the SLP method has been quite mature, but it is found that its application in the field of meat production is very little. Ojaghia et al. used the SLP method to develop an optimized layout when researching meatball and soup processing company. The results showed that the production efficiency of the new layout increased by 4.35% [7]. Due to the particularity of meat products, timeliness of production and market demand need to be taken into account. Therefore, we use the improved SLP method for meat product workshop layout optimization. Shirai et al. proposed that orders from different customers lead to fluctuations in its delivery date and lead time, and different orders affect the operation of the production system. The impact of orders for meat products on the production process should be considered [8]. Firstly, we use date, main, quantity, routing, supporting service, and time (DMQRST) factors instead of product, quantity, routing, supporting service, and time (PQRST) factors. The improved method can avoid the phenomenon of insufficient production in holidays and daily overproduction. The layout of meat product workshop should be optimized according to the process flow of main products (products with high market popularity). Secondly, we analyze workshop layout problems by the F-D method, not only on the basis of experience. Finally, personnel diversion should be considered to avoid personnel pollution.

The rest of the paper is organized as follows. Section 2 introduces the improved SLP method. In Section 3, we introduce the layout of the workshop and analyze the problems with F-D method. In Section 4, we analyze the logistics relationship and non-logistics relationship to get the optimization scheme. Finally, the conclusions are presented in Section 5.

2. Improvement of SLP Method.

2.1. Traditional SLP. SLP method is commonly used in layout design, and the method includes production, quantity, routing, supporting service, and time. The main process is as follows. Firstly, we determine the relevant information of P, Q, R, S and T. Then, we consider the logistics relationship and non-logistics relationship. Finally, we draw the comprehensive diagram of the relationship among operating units. With the continuous development of technology, the problems in the layout optimization of the traditional SLP method in different occasions appear gradually. The traditional SLP has many limitations in the optimization research of meat product workshop. For example, the layout does not take account of the actual situation of the enterprise. The optimization is according to the managers' experience, and the layout does not consider character diversion as well. We have improved the traditional SLP method based on the characteristics of R Company's meat product workshop as an example.

2.2. Improved SLP method. In order to overcome the limitations of the traditional SLP method in the meat product workshop, the following improvements are proposed.

1) We combine the actual situation of the enterprise. We respond to just in time (JIT) production mode, and produce the required quantity of the product. The sales volume of meat products increases before holidays. The phenomenon of insufficient production during holidays and overproduction on normal days should be avoided. Therefore, the time factor (Date) should be combined to calculate the material flow among operating units in years or months. The formula is as follows.

$$Material\ flow = working\ days \times daily\ output. \tag{1}$$

Sales volume determines production when meat products are marketed. The main products (Main) should be taken as the research object to facilitate production when the facility layout is rearranged. The main products include the products of highest selling and the products that customers like. Therefore, DMQRST should be used when optimizing the layout of meat product workshop.

2) We use F-D analysis of workshop. Firstly, the volume of material handling and inventory are considered to draw the material flow from-to table. Then, we use the distance length of the center point of each operating unit to draw the logistics distance from-to table. Finally, the logistics distance is taken as the horizontal coordinate, and the material flow as the vertical coordinate to draw the F-D analysis diagram. We identify the problems in the meat product workshop by logistics intensity. The formula for calculating logistics intensity is as follows.

$$\textit{Logistics intensity} = \textit{material flow} \times \textit{logistics distance.} \tag{2}$$

3) We consider the situation of human diversion. The order of operating units for meat products cannot be freely changed. Products should be transported through conveyor belts after being disinfected and air dried. Therefore, the layout should not be carried out only by logistics relations and non-logistics relations.

3. Current Situation and Problem Analysis of Workshop Layout.

3.1. Current layout of workshop. R Company was founded in 2001 with an area of 46,000 square meters. The layout of the workshop is a rectangle with a length of 90 m and a width of 30 m. The current layout of the workshop is shown in Figure 1.

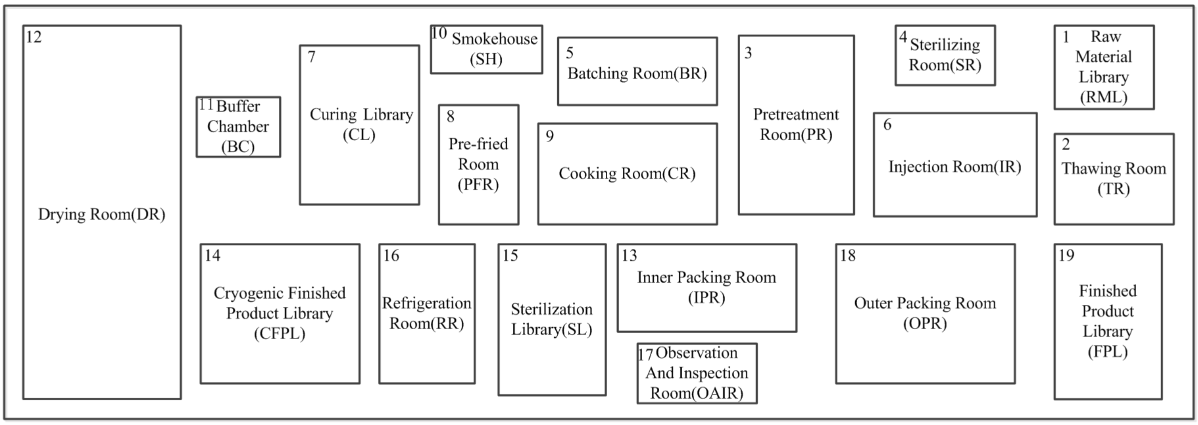

Figure 1. Layout of workshop

There are 19 operating units in the workshop layout. The number of machines, floor area and activity area of each operating unit are different. The floor area of each operating unit is shown in Table 1.

Table 1. Division and area of operation units (m^2)

Region name	Area	Region name	Area	Region name	Area	Region name	Area
1-RML	64	6-IR	120	11-BC	20	16-RR	90
2-TR	80	7-CL	100	12-DR	360	17-OAIR	26
3-PR	100	8-PFR	80	13-IPR	144	18-OPR	190
4-SR	38	9-CR	120	14-CFPL	140	19-FPL	160
5-BR	94	10-SH	20	15-SL	120		

The three main products of the production workshop are obtained according to the output comparison and actual research. The information of different products is shown in Table 2.

Table 2. Information of different products

Product type	Quality/t	Working days/day	Production rate/%
White striped chicken	642	300	80
Wing tip	1.5	285	60
Toothpick meat	0.85	280	140

3.2. **F-D analysis.**

1) The distance among each operating unit can be measured according to the process flow of the three products. The distance among operating units is selected using the distance of the center point of each operating unit for approaching the actual distance as much as possible. The distance from-to table is shown in Table 3.

Table 3. Logistics distance from-to table (m)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	7																	
2		20																
3			9															
4				20														
5					26	16		7										
6						28												
7							11			10								
8								13		22								
9						24			19									
10										29								
11											10							
12												34				42		
13														15				
14																		
15															8			
16																20		
17																	22	
18													55					14

2) The annual flow of material can be calculated based on the annual volume of material handling and inventory among operating units. The annual flow of material among operating units is plotted as shown in Table 4.

3) By calculating the product of material flow and logistics distance, the F-D analysis diagram is obtained as shown in Figure 2. The coordinate system is divided into four regions, with 24 points in total. Region I is the most ideal area. Region IV is related to customer needs, holiday sales policies, etc., and can be improved by reducing production demand reasonably. Region III does not need to be improved. The transport distance among operating units in region II is long and the handling routes are crossed. Therefore, it is the points in region II that should be improved. Reasonable layout can improve production efficiency of the workshop effectively.

3.3. **Problems in the workshop.** Based on on-site investigation of the workshop and analysis of the F-D diagram, it is found that there are some problems in the workshop. Firstly, the layout of the workshop is unreasonable. For example, there is a large blank area next to the buffer chamber; there are serious logistics route intersections near the injection room and curing library. Secondly, the long-distance transportation wastes a lot of manpower and material resources. For example, the transportation distance from the

Table 4. Material flow from-to table (t)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	805																	
2		765																
3			765															
4				746														
5					1493	0.81		1.4										
6						1500												
7							884			1.32								
8								706		1.32								
9						1.5			706									
10										700								
11											702							
12												644				1.56		
13														660				
14																		
15															660			
16																665		
17																	640	
18													1.19					671

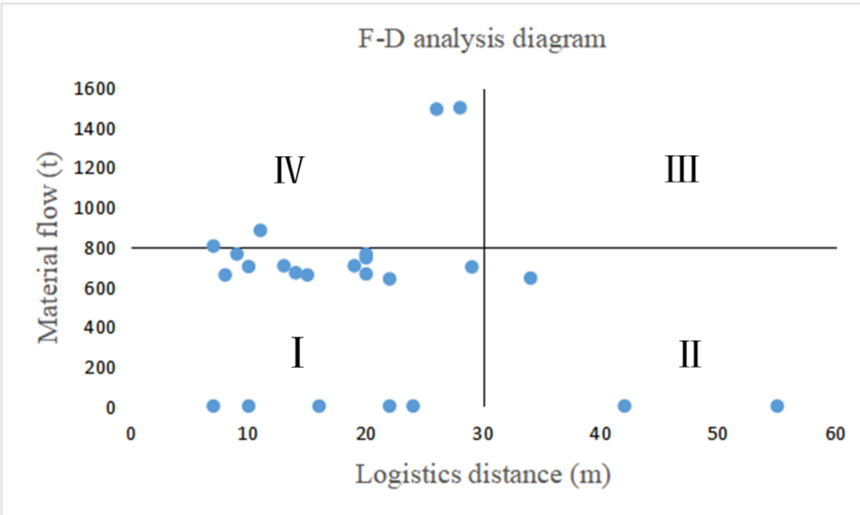

Figure 2. F-D analysis diagram

outer packing room to cryogenic finished product library is up to 55 meters, and the long-distance transportation results in excessive logistics intensity. Finally, the phenomenon of people shunt is not obvious.

4. Workshop Layout Optimization Based on Improved SLP Method.

4.1. Analysis of logistics relations. The logistics volume and distance between two operating units are represented by Q_{ij} and D_{ij}, and the logistics intensity of the workshop is represented by F_{ij}. Therefore, the logistics intensity formula is as follows.

$$F_{ij} = Q_{ij} \times D_{ij}. \tag{3}$$

The logistics intensity level is represented by A, E, I, O and U, which respectively correspond to super high, extra high, high, general and negligible logistics intensity. A,

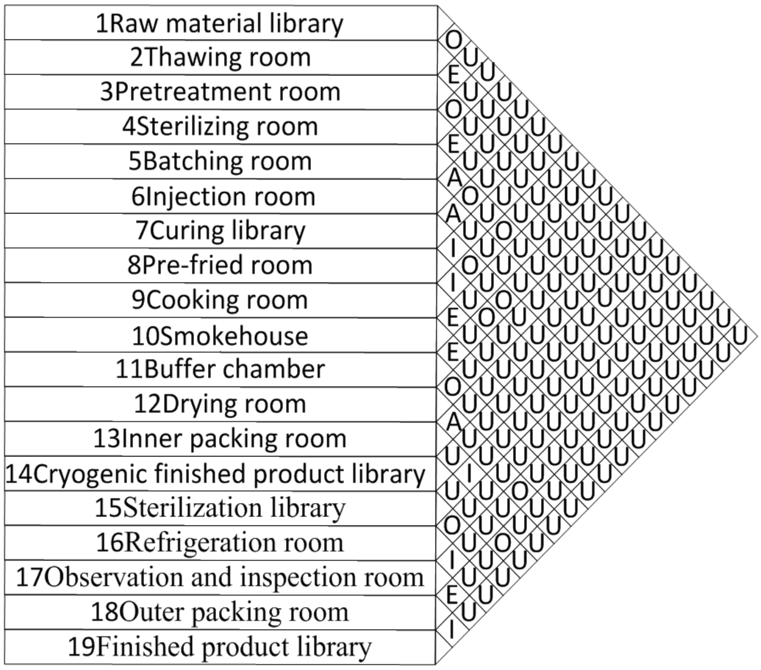

FIGURE 3. Correlation diagram of logistics

E, I, and O respectively account for 10%, 20%, 30%, and 40% of the total operating units. The logistics diagram is shown in Figure 3.

4.2. **Analysis of non-logistics relations.** Non-logistics relationships include the closeness among operating units, workshop safety and quality management, workshop 5S, personnel management, etc. The closeness level is divided into A, E, I, O, U and X, which correspond to absolutely necessary proximity, particularly important proximity, important, average, not important, and not to be closed. The determinants affecting non-logistics relationship are shown in Table 5.

TABLE 5. Determinants of the relationship among operating units

Number	Determining factor	Number	Determining factor
1	Continuity of work flow	5	Safety and pollution
2	Production service	6	Work closely
3	Ease of material handling	7	Vibration, noise, smoke
4	Efficient management	8	Personnel contact

According to the non-logistics grade table, the non-logistics relationship diagram among all operating units can be obtained, as shown in Figure 4.

4.3. **Comprehensive location correlation map.** The weight ratio between logistics and non-logistics is determined to be $m : n = 1 : 1$. The comprehensive relationship between logistics and non-logistics among all operating units is obtained, as shown in Figure 5.

4.4. **Workshop layout improvement plan.** There are many logarithms of mutual relationships among operating units. We draw a correlation map of each operating unit positions based on the score of comprehensive proximity, as shown in Table 6.

The map of the location of homework units can be drawn based on the ranking of scores and the relationships among operating units.

The workshop optimization scheme is proposed according to Figure 6. It should be noted that the area before and after drying room cannot be mixed distribution, as shown

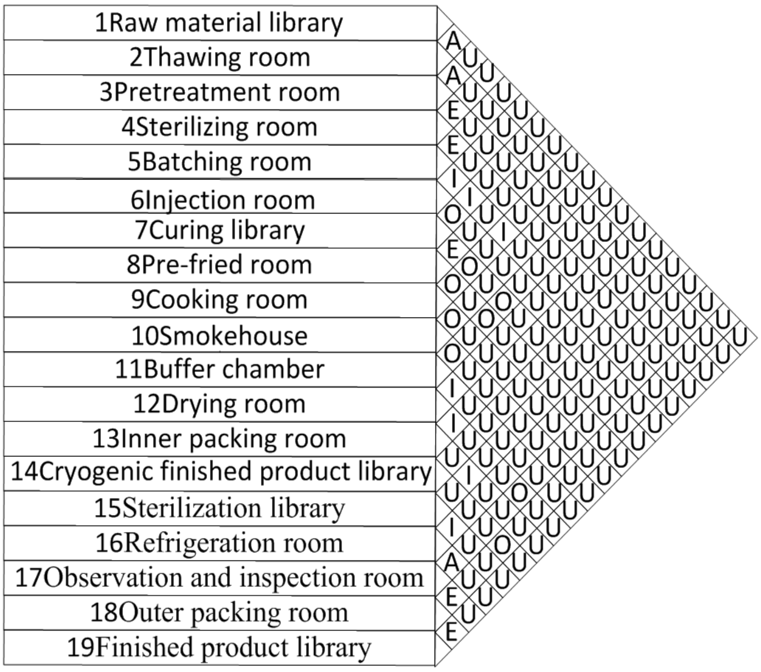

Figure 4. Non-logistics correlation diagram

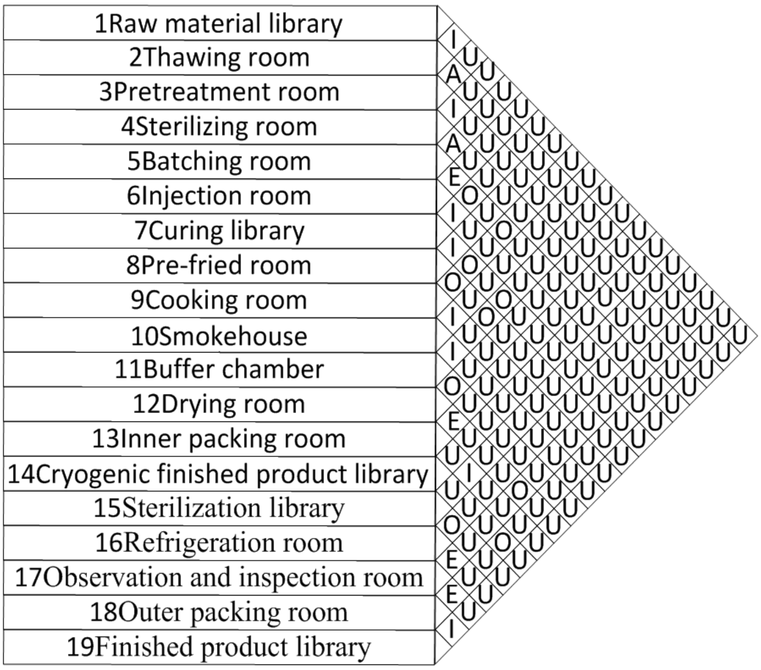

Figure 5. Comprehensive correlation diagram of logistics and non-logistics

Table 6. Comprehensive proximity of each operating unit

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Synthesize	2	6	6	6	9	5	7	4	5	4	5	6	6	1	3	4	6	5	2
Sort	17	3	4	5	1	9	2	13	10	14	11	6	7	19	16	15	8	12	18

in Figure 7. The area of each operating unit has not changed before and after optimization, but only the position has changed.

4.5. **Evaluation of new schemes.** There are many evaluation methods for layout schemes. We choose the graded weighted scoring method. This method can compare various

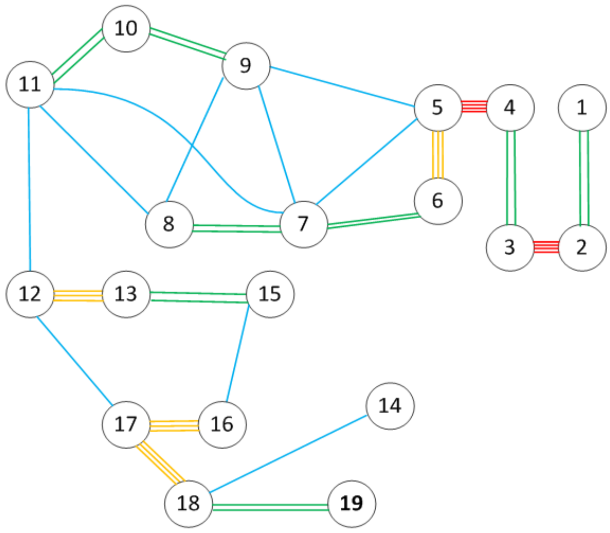

FIGURE 6. Location correlation diagram of operating units

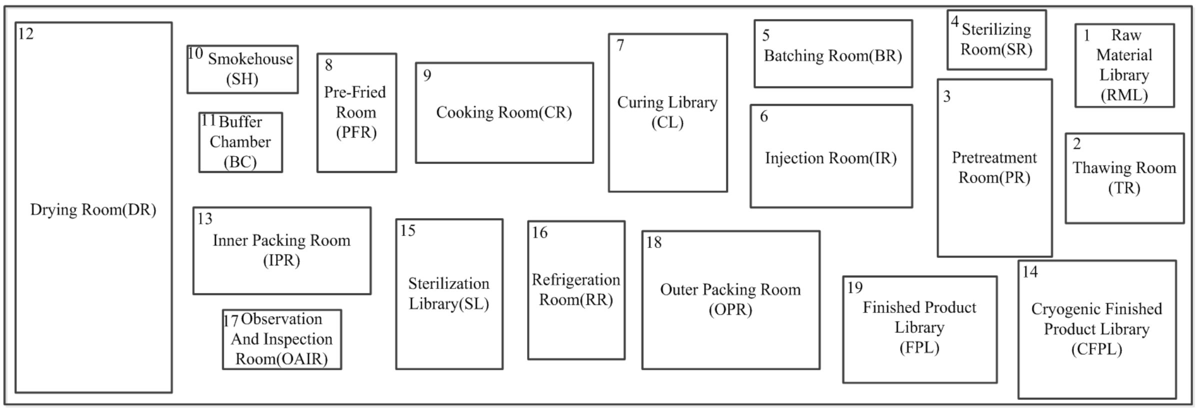

FIGURE 7. Workshop layout after optimization

TABLE 7. Layout scheme evaluation table

Evaluation factor	Weight	Original layout rating/score	New layout level/score
Material handling crossover	10	I/16	E/30
Space utilization rate	8	E/26	E/26
Personnel mobility	5	O/5	I/10
Manageability	7	O/7	I/14
Facilitate communication and information transfer	6	I/12	E/28
Facilitate work contact	4	I/12	I/12
Conducive to the environment	3	O/6	O/6
Composite score		84	126

non-economic factors conveniently, and the selection of evaluation factors is based on the influencing factors of non-logistics relationships and expert evaluation. We score by on-site construction personnel and safety management personnel, and assign weights and levels to each factor. A = 4, E = 3, I = 2, O = 1, and U = 0 represent very good, good, relatively good, average, and bad. The results are shown in Table 7.

It can be seen that the new layout has many advantages from the comprehensive score. The new layout shortens the distance of handling, improves communication among

Table 8. Optimization of the logistics intensity of the front and rear layout (t·m)

Route	Before	After	Route	Before	After	Route	Before	After
1-2	5635	5635	7-8	9724	23868	12-13	21896	10948
2-3	15300	7650	7-11	13.2	46.2	12-17	65.52	15.6
3-4	6885	5355	8-9	9178	9178	13-15	9900	9900
4-5	14920	5222	8-11	29.04	9.24	15-16	5280	5280
5-6	38818	10451	9-7	36	21	16-17	13300	10640
5-7	12.96	8.1	9-10	13414	13414	17-18	14080	17920
5-9	9.8	35	10-11	20300	5600	18-14	65.45	34.51
6-7	42000	16500	11-12	7020	7020	18-19	9394	9394

work units, and facilitates information transmission. Detailed logistics evaluation data are shown in Table 8.

The original layout logistics intensity is 257275.97 t·m, while the optimized layout logistics intensity is 174144.65 t·m. The optimization rate has reached 32.3%. The optimized layout reduces logistics intensity effectively.

5. **Conclusions.** Without changing the main structures of the workshop, it is feasible to optimize the layout of R Company's meat product workshop by applying the improved SLP method. The added time and product factors of the improved SLP method avoid production waste and insufficient production. The new layout reduces the intensity of production logistics and the duplication of logistics routes. It has been proven that the improved SLP method achieves the goal of improving the overall management level of the meat product workshop, and it is easy to operate with strong practical feasibility. In addition to the meat product industry, the improved SLP method can also provide reference value for other manufacturing enterprises to lay out their workshops. Layout optimization and simulation techniques should be combined in the following research. Simulation technology can be used to simulate and compare the production of new and old layouts to verify the practicality of the optimization plan.

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