

# Workshop Layout Optimization Based on SLP and Genetic Algorithm

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**Abstract:** In response to the existing problems in the layout of Company B's production workshop, the System Layout Design (SLP) method is used to obtain the logistics intensity and non logistics intensity between operating units in the workshop. Based on comprehensive correlation analysis, a position correlation map is drawn to obtain the initial layout of the workshop. In order to eliminate the drawbacks caused by human factors, genetic algorithms were used to optimize the initial layout, forming a more scientific and reasonable layout plan. The feasibility of the optimized layout was verified by comparing the handling distance and logistics intensity.

**Keywords:** Layout optimization, System layout design method, Genetic algorithm.

## 1. Introduction

As the main body of national economic development, the manufacturing industry plays an important role in promoting high-quality economic development and enhancing national competitiveness. Facility layout planning is an important part of enterprise development, and the quality of layout planning will have a significant impact on the production efficiency, material turnover efficiency, factory equipment utilization, and material processing costs of the enterprise. Therefore, a scientifically reasonable facility layout can reduce the overall management cost of material handling in the workshop by 10% to 30% [1]. If this cost can be significantly reduced through a scientifically reasonable facility layout, it is equivalent to creating profits for the enterprise and promoting its long-term development [2]. At present, there are two mainstream methods for workshop equipment layout, System Layout Planning (SLP) and Genetic Algorithm. The SLP method proposed by American industrial engineer Charlie has been widely applied in the production research of automotive manufacturing and other manufacturing enterprises [3]. Some foreign scholars have conducted extensive research on the job relationship diagrams and material handling diagrams generated during the application of SLP and Material Handling Analysis (SHA) methods [4-6]. B Deng et al. Combined SLP and genetic algorithm to optimize the equipment layout model, which reduced material processing costs and improved the utilization rate of the production workshop [7]. Ju Jingjing et al. developed a workshop layout optimization model based on ergonomics, using traditional SLP and genetic algorithm to optimize and solve the model, and verified it through examples [8]. A large number of studies have shown that SLP is a relatively mature method for solving the layout of warehouse centers, but this method is subjective and easily influenced by the experience of researchers, so it needs to be combined with other optimization algorithms for quantitative analysis. This article combines the SLP method with genetic algorithm to optimize the workshop layout of Company B, achieving complementary advantages between the two and making the workshop equipment layout more practical.

## 2. SLP Solution for Initial Layout of Production Workshop

### 2.1. Overview of the Production Workshop of Company B

B Company is a German brand manufacturer of electric tools and accessories. The products produced by the factory mainly include electric drills, electric hammers, electric pickaxes, charging tools, angle grinders, etc.. Factory B covers an area of approximately 30000 square meters, with a production workshop of 100m in length and 88.5m in width, covering an area of 8850 square meters. The current layout of the workshop is shown in the following figure.

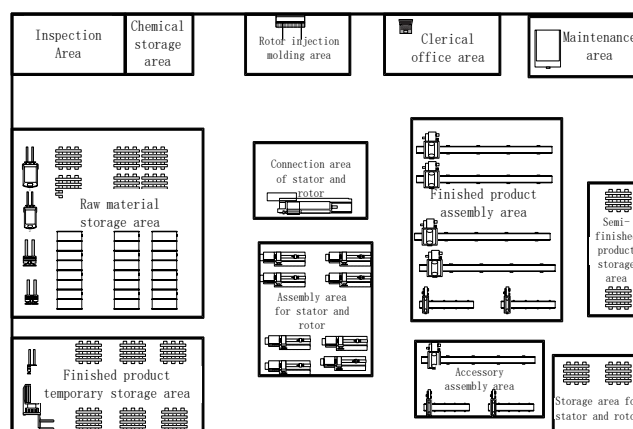


Figure 1. Original layout of the workshop

In the figure, it is evident that the workshop facilities are arranged in an unreasonable manner, such as the distance between the raw material storage area and the finished product assembly area being too far, the phenomenon of repeated handling in the inspection area, and the process of transferring the stator and rotor to the stator and rotor storage area and then to the finished product assembly area being not only too far away, but also with severe repeated handling.

## 2.2. Analysis of Logistics and Non-Logistics Relationships

### 2.2.1. Analysis of Workshop Logistics Relationship

The logistics intensity in the workshop is determined by the process route and logistics volume. According to the transportation frequency between homework units, the logistics relationship strength is divided into 5 levels. The higher the transportation frequency, the higher the level of logistics relationship, commonly represented by A, E, I, O, U, and their degree varies from strong to weak. Based on the logistics distance and logistics intensity between the operating units in the production workshop of Factory B, the logistics relationship between the operating units is obtained (see Figure 2).

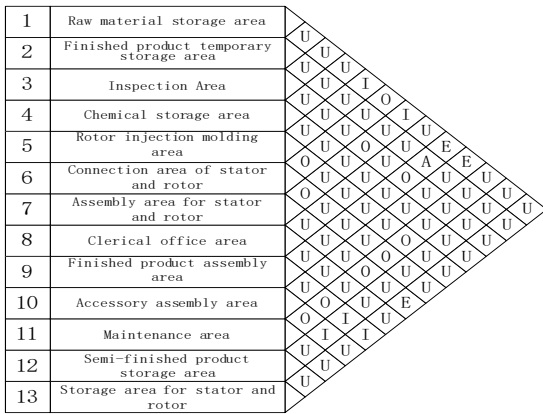


Figure 2. Logistics intensity relationship chart

### 2.2.2. Analysis of Workshop Logistics Relationship

When planning the layout of workshop facilities, not only should the impact of logistics relationships be considered, but also the impact of non-logistics relationships on production, mainly including the continuity of the operation process, the weight of material handling, convenient handling, and management, in order to determine the non-logistics relationships of the operating unit (see Figure 3).

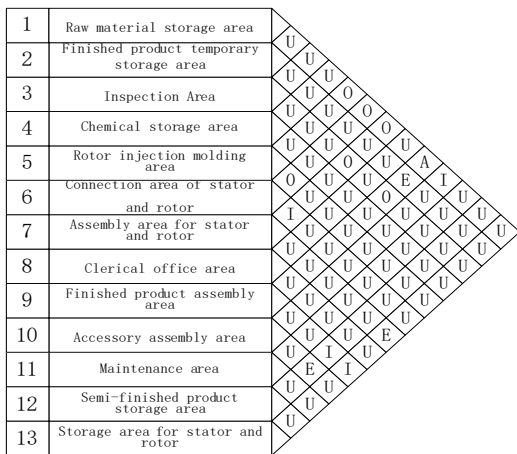


Figure 3. Non logistics relationship diagram

## 2.3. Comprehensive Relationship and Initial Workshop Layout

In the vast majority of factories, there are both logistics and non-logistics connections between the operating units. Therefore, in SLP, it is necessary to assign points based on the logistics and non-logistics relationships between the operating units, weighted and summed according to a certain proportion, and graded according to the proportion described

in the table. Finally, the composite interrelationship, which is the comprehensive interrelationship, is calculated. This article sets the weight ratio between logistics and non-logistics relationships as 1:1. The classification of comprehensive interrelationships is shown in the table. The comprehensive interrelationships between all 36 job pairs between job units 1 and 13 were calculated using weights. Finally, obtain a comprehensive interrelationship diagram and preliminary layout diagram of the homework unit (see Figure 4 and Figure 5).

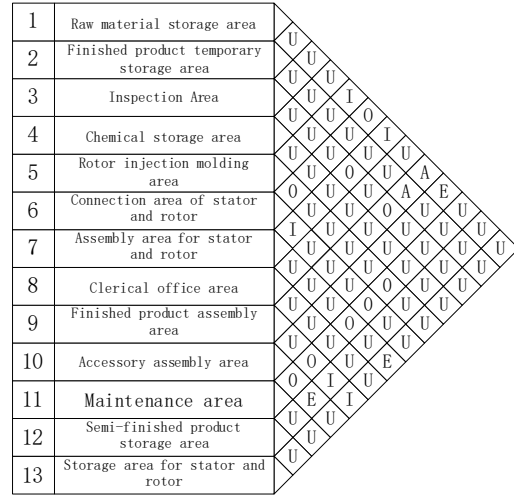


Figure 4. Comprehensive Mutual Relationship Diagram

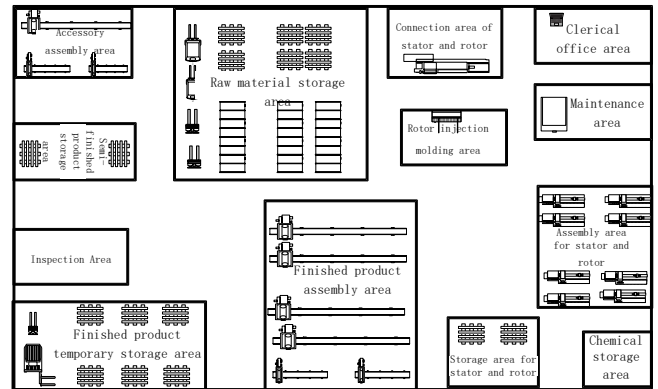


Figure 5. Production workshop layout diagram

## 3. Workshop Layout Optimization Based on SLP and Genetic Algorithm

The most commonly used algorithm at present is still the Qualitative Processing System Layout Planning (SLP) algorithm, which cannot plan and design the specific location of facilities, and the solution is difficult to determine due to the subjective will of decision-makers.

The SLP method focuses on the continuity of the process and the rationality of the workshop layout. The judgment of the superiority or inferiority of the workshop equipment layout relies too much on the experience of designers, and lacks quantitative analysis of the workshop, resulting in the inability to intuitively and scientifically determine whether the layout is optimal. Therefore, to establish a mathematical model for the processing workshop, with the goal of minimizing logistics costs and maximizing non logistics relationships, a genetic algorithm is designed and solved through MATLAB programming.

### 3.1. A Mathematical Model for The Production Workshop Problem in Factory B

#### 3.1.1. Model Assumptions

This article aims to optimize the layout of Company B's production workshop to minimize material handling costs. To achieve this goal, a layout optimization model was established based on facility layout theory and objectives. The model assumes that:

(1) The boundaries of all workshop units are parallel to the X or Y axis. The X-axis positive half axis serves as the long side direction of the factory, and the Y-axis positive half axis serves as the wide side direction of the factory;

(2) The center point of each unit serves as its entry and exit points;

(3) The unit transportation cost between different work units is roughly equal.

(4) The distance between two workshops is calculated as the Manhattan distance, which is  $d_{ij} = |x_i - x_j| + |y_i - y_j|$ .

The layout coordinates of Company B's production workshop are shown in Figure 6.

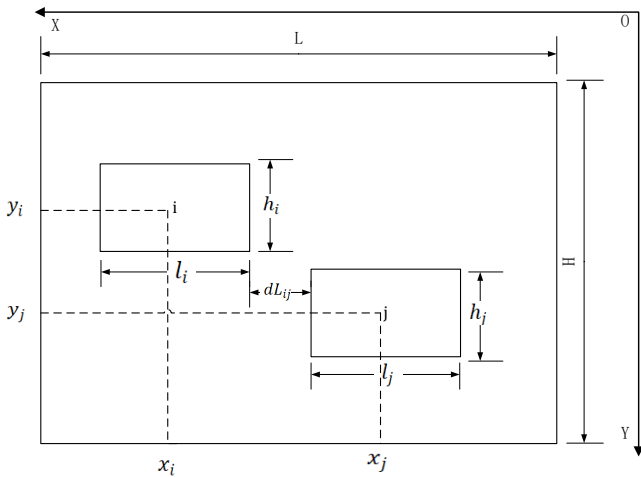


Figure 6. Coordinate map of homework unit

#### 3.1.2. Model Assumptions

Based on the description of the above layout problem, a single objective function is established to minimize the material flow rate under a certain workshop area, following the principles of shortest transportation path and optimizing workshop layout, in order to achieve the goal of reducing material flow rate. Key considerations should be given in production layout. Let  $i$  and  $j$  be the work units in the layout plan,  $d$  be the distance between two work units,  $f$  be the handling volume between two work units, and  $C$  be the unit logistics cost. Then, the expression for the material handling cost function:

$$C = \sum_i^m \sum_j^m c_{ij} f_{ij} d_{ij} \quad (1)$$

#### 3.1.3. Constraint condition

(1) When planning the workshop layout, consider the transportation route, set the distance between each unit, and ensure that any two workshops in the factory area do not overlap in the workshop area.

$$|x_i - x_j| \geq \frac{L_i + L_j}{2} + dL_{ij} \quad (2)$$

$$|y_i - y_j| \geq \frac{H_i + H_j}{2} + dH_{ij} \quad (3)$$

(2) Ensure that the edge of the workshop does not exceed the boundary of the factory area.

$$L \geq |x_i - x_j| + \frac{L_i + L_j}{2} \quad (4)$$

$$H \geq |y_i - y_j| + \frac{H_i + H_j}{2} \quad (5)$$

#### 3.1.4. Initialize the Group

Before starting the calculation, the genetic algorithm needs to generate a certain number of populations to facilitate subsequent operations. In population intelligence algorithms, having too many populations can lead to increased computation time, unstable convergence, and reduced efficiency; A small population can lead to a lack of diversity within the population, resulting in suboptimal outcomes. To prevent this situation; The initial layout planning scheme obtained by the SLP method can be combined with randomly generated individuals to manually adjust the initial population and create a diverse optimal initial population.

#### 3.1.5. Fitness Function

The fitness function, also known as the evaluation function, has a higher fitness value, which increases the chance of an individual being selected as a parent, surviving, and passing on their advantageous traits to offspring. Individuals with lower fitness values are more likely to be eliminated. This process ensures that ideal traits are continuously inherited, ultimately forming the best individual solution. In the process of facility layout in this case, several constraints and objective functions were encountered. Based on the mathematical model, a fitness function was formed using the reciprocal method. This article studies the minimum value problem and adopts the first processing method, so the objective function is:

$$F(x) = \frac{1}{1 + G + f(x)} \quad G \geq 0, \quad G + f(x) \geq 0 \quad (6)$$

Wherein,

$$f(x) = C' \quad (7)$$

$$G = 1000 \quad (8)$$

#### 3.1.6. Cross and Variation

Genetic operators are an important component of genetic algorithms, which mimic natural selection to select the most suitable individuals. It consists of four basic operations: selection, crossover, mutation, and mutation. This article uses real number encoding to select partial crossover and single point mutation. Partial crossing refers to the selection of a subset of genes at a fork point for mutual exchange; Single point variation refers to the variation of each gene in an individual's gene sequence, replacing the original gene on the individual's gene pair with a small probability.

### 3.2. Model Algorithm Solving

Write and run a genetic algorithm program using MATLAB, with som the running results shown in Figure 7 and Figure 8.

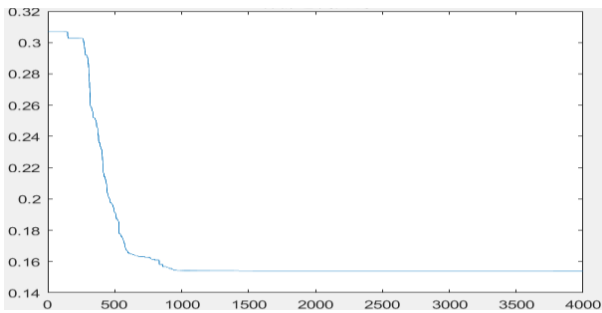


Figure 7. Particle iteration process

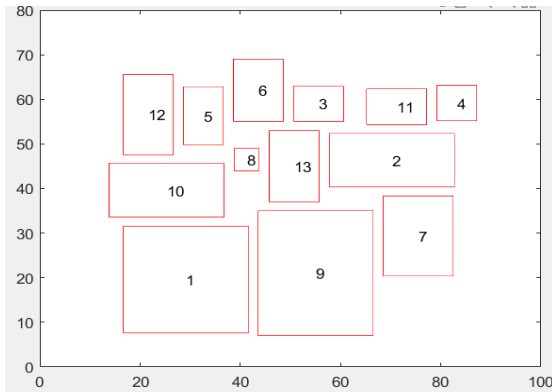


Figure 8. Optimized facility layout diagram

Based on the actual situation of the factory and the optimal unit coordinates and area requirements, draw an optimized layout diagram (as shown in Figure 10).

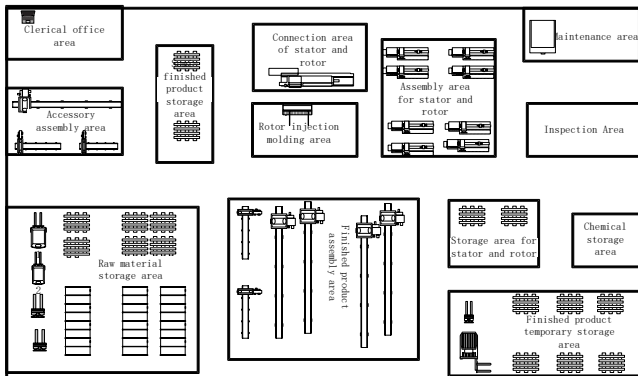


Figure 9. Optimized workshop layout diagram

## 4. Result Analysis

To test the effectiveness of the optimized facility layout, the distance and transportation volume of work units before and after the optimization of the workshop layout in Company B are shown in Table 1.

Table 1. Three Scheme comparing

Related units	Distance before optimization/m	Optimized distance/m	logistics volume/t
9-2	68	28	4.8
1-9	62	30	2.3
1-10	57	26	1.5
7-13	47	38	1.2
10-12	26	19	1.5
13-9	21	20	1.2
12-9	17	42	1.4
1-7	23	54	0.8
1-5	28	25	0.5
6-7	15	21	0.5
5-6	14	17	0.5
1-6	21	52	0.2
9-3	65	43	0.05

According to Table 1, the total logistics distance before optimization is 464m, and the total logistics distance after optimization is 415m. The total flow rate product before optimization is 7596, while the total flow rate product after optimization is 4905. The total logistics distance of the optimized plan has been reduced by 49 meters, with an optimization ratio of about 11%; The total flow rate has decreased by 2691 compared to the product sum, with an optimization ratio of approximately 35%.

## 5. Conclusion

This article takes the production workshop of Company B as the research object, establishes a preliminary improvement plan for workshop layout through SLP method, and optimizes the initial workshop layout plan using genetic algorithm. The results indicate that the new plan can reduce logistics and transportation costs and effectively help Company B improve the efficiency of the production workshop.

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