Research on the Layout of Hydraulic Cylinder Workshop Based on SLP Intelligent Algorithm

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Abstract. With the rapid development of the global economy, the hydraulic cylinder industry has also ushered in a period of booming development. For L busines's hydraulic cylinder plant faces high material transportation efficiency, which is mainly due to its cluttered plant layout. This situation was addressed by organically incorporating the SLP method with genetic algorithms to achieve an optimal plant layout for the hydraulic cylinder manufacturing process. After a comprehensive analysis, an effective solution was developed which can effectively solve a variety of problems such as logistical and non-logistical relationships, area utilisation, etc., thus significantly shortening the production cycle time, ensuring high product quality, and effectively saving the use of space.

Keywords: Workshop layout · SLP method · Genetic algorithm

1 Introduce

In recent years, innovative directions in many industries have been promoted due to the growth of the global economy. However, many industries still face many challenges, such as confusing material handling systems and long handling distances in factories, which reduce the efficiency of factory transport and increase the operating costs of companies. Shop floor layout optimisation is an essential part of the business. Shop floor layout optimisation helps companies to achieve high internal economic efficiency, optimise shop floor logistics systems, save manpower and materials and save transport materials. Cao Yanghua applied the SLP method to determine the close relationship between its equipment, evaluate the two feasible parties and select the final layout plan [1]. Gan Weihua et al. studied busines F, applied the SLP method to find a better layout solution and analysed the rationality of the layout in terms of handling costs and plant rental costs [2]. Yun Qingqian studied the layout of a factory production plant and adjusted the layout of the plant with the objective of improving efficiency to obtain the layout of the plant facilities in the ideal state [3]. Ye Mujing derived the initial solution through the SLP method and used this layout as the initial population of the genetic algorithm to further solve for a better layout [4]. Ai Dong takes machinery manufacturing enterprises as the research object, establishes the objective function by reducing the logistics handling and shortening the production cycle, and optimises the layout using an improved particle swarm algorithm [5]. Zhou Jiaojiao introduces the fatigue factor

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for analysis when studying the layout optimisation problem, establishes a mathematical model by considering logistics factors and human factors, and solves the layout scheme by simulated annealing algorithm, the new scheme effectively reduces the human fatigue value [6]. Jingfa Liu uses a multi-objective particle swarm algorithm to solve its Pareto chart with material handling cost, non-logistics relationship and the utilisation rate of the workshop as the objective function [7]. Guan Chao proposed a new multi-shop facility layout by arranging a group of departments into multiple workshops, and combined it with a multi-objective particle swarm optimisation algorithm for optimisation and evaluation [8]. Zhou Yanmei investigated the use of SLP for a certain factory layout and improved the problematic links [9]. Jiang Liangkui, to establish a mathematical model based on the characteristics of a flexible manufacturing shop, with the objective of minimising material handling costs and facility costs, solving the mathematical model by immune genetic algorithm and finally verifying the validity of the results [10].

This paper takes the hydraulic cylinder workshop of busines L as the research object, with the help of the traditional system layout method SLP, combined with intelligent algorithms to optimize the layout design of this workshop, in order to achieve the optimal layout effect and help the busines and this type of enterprises to provide scientific and reasonable solutions.

2 Current Status of Workshop Layout

2.1 Workshop Production Type

L busines mainly produces hydraulic cylinders and it presents the characteristics of multi-species, variable batch, personalization and high profit, so the hydraulic cylinder is the object of study. The choice of hydraulic cylinder as the object of study can reduce the production cost of the enterprise more and help to create higher profits for the enterprise.

2.1.1 The Current Layout of the Workshop

The workshop currently occupies an area of 6,000 m^2, of which 120m long and 50m wide, with a large door on the long side, a number of windows on the wide side and a small door leading to the office, which is well ventilated. Under the production department, the workshop is subdivided into 11 zones, which are raw material storage, under the material area, casting area, experimental area, machining area, welding area, painting area, assembly area, finished products area, cleaning area, the current layout of the workshop and the related area are shown in Fig. 1 and Table 1.

2.1.2 The Order of Flow Between Operating Units

Hydraulic cylinder production process is firstly in the casting workshop to cast and process raw materials into various forgings, castings, round steel parts and other blank parts, there are also some raw materials directly to its welding and assembly into semi-finished products or machining, and then through the machine equipment to a variety of blank parts need to go through turning, milling, planning, grinding, boring, drilling, and other processes for cutting and processing, after processing part of the parts transported to

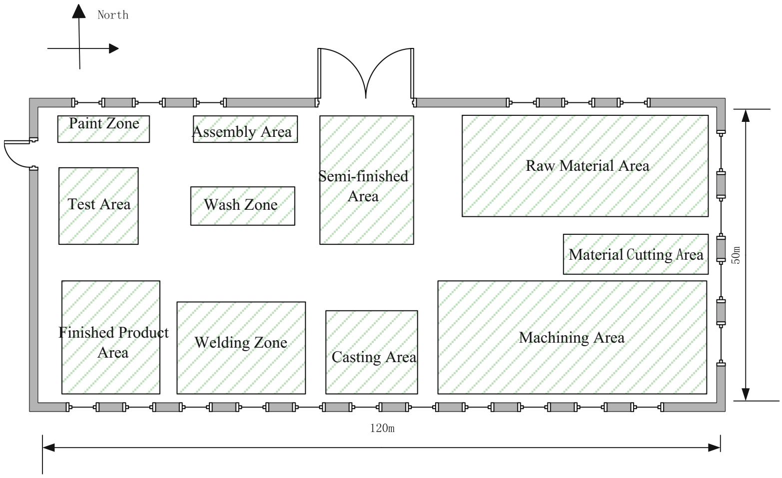

Fig. 1. Workshop layout diagram

Table 1. Main functional areas and area division

No	Job Unit Name	Area m^2
1	Raw Material Area	800
2	Material Cutting Area	200
3	Casting Area	150
4	Machining Area	525
5	Welding Zone	250
6	Wash Zone	200
7	Assembly Area	300
8	Test Area	256
9	Paint Zone	210
10	Semi-finished Area	375
11	Finished Product Area	500

the assembly workshop, part After processing, some parts are transported to the assembly workshop, and some outsourced and outsourced parts are transported directly from the raw material store to the assembly workshop, where they are assembled together with other parts in the assembly workshop. After assembly, they enter the test area to check the performance of the products and the quality indicators, and after the performance indicators are checked, they are painted.

2.1.3 F-D Analysis

F-D analysis method, also known as flow distance analysis method, analyzes the layout of the workshop based on this analysis method, identifies existing problems, and improves them to propose corresponding solutions. With the transportation distance as the abscissa and the logistics volume as the ordinate, draw all the points composed of transportation distance and logistics volume in a Cartesian coordinate system system, and then divide this coordinate system into 1, 2, 3, and 4 areas, so that you can more intuitively observe the logistics relationship between the operating units in the workshop, as shown in Fig. 2. The logistics flow, distance, and distance product of each workshop are shown in Table 2.

The distance calculated based on the Manhattan distance formula.

Area 1 represents the work unit pair with a high material flow rate and close transportation distance. When planning the layout of the workshop, area 1 is the reasonable work unit pair layout, and compared with the other three areas, area 1 is in line with the objective and practical layout. Area 2 represents the work unit pair with higher material flow and transport distance. In the process of product production, material handling costs are the highest, and the handling time is long and easily affects the production progress of upstream and downstream work units, which in turn affects the production efficiency of the whole workshop. If there are work unit pairs with a long transport distance and a large volume of material in the workshop, the smaller volume of material and the work unit pairs with a long transport distance will have an impact on the work unit pairs with a large volume of material and a long transport distance in the workshop planning and

Table 2. Workshop material flow, distance and distance product table

No	Job Unit Pairs	Transportation Distance (m)	Cargo Flow (t)	Measure the Distance Product (t·m)
1	1-2	29	990.95	28737.55
2	2-3	64	37.23	2382.72
3	2-4	21	760.03	15960.63
4	3-4	70	34.48	2413.60
5	4-6	80	1006.13	80490.40
6	4-8	108	285.48	30831.84
7	5-4	60.5	585.35	35413.67
8	6-10	60	1006.13	60367.80
9	7-8	40	1032.34	41293.60
10	7-10	62	171.36	10624.32
11	8-5	75	285.48	21411.00
12	8-9	18.5	1032.34	19098.29
13	9-11	39	1032.34	40261.26
14	10-5	33.5	352.79	11818.46
15	10-7	62	653.42	40512.04

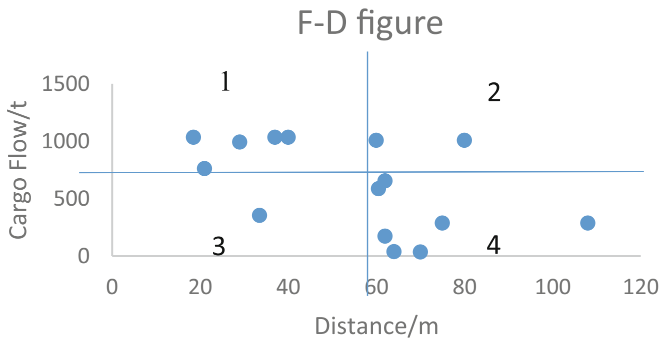

Fig. 2. F-D diagram between work units

layout, resulting in a chaotic logistics route in the workshop; Area 4 indicates work unit pairs with a small volume of material but a long transport distance. When planning the layout, the transport distance of the area 4 pairs should be reduced as much as possible while ensuring that the higher logistics and transport distance pairs are arranged in a reasonable manner. Attention also needs to be paid to operation pairs close to the regional line.

3 SLP-Based Initial Layout Solution

3.1 Workshop Logistics Relationship Analysis

The logistics intensity between different processing areas is the most important factor in the SLP analysis process, and is also the main reference indicator in the plan layout optimization process, so the logistics intensity between each processing area needs to be summarized and analyzed. Based on the above comprehensive study of the logistics relationship, the logistics correlation diagram is collated, as shown in Fig. 3

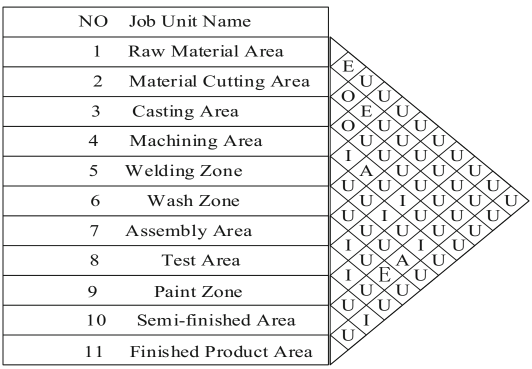

Fig. 3. Logistics related diagram of the work unit

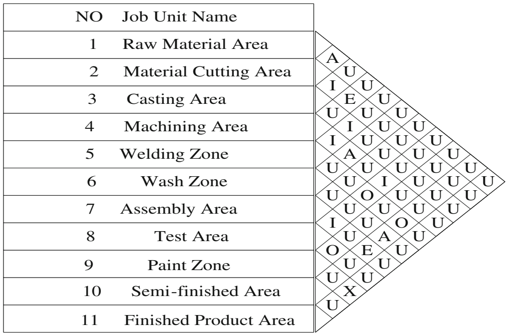

Fig. 4. Non-logistics interrelationship diagram

3.2 Analysis of the Non-Logistics Relationship in the Workshop

In the actual production process, for the workshop layout not only logistics intensity and other objective factors have a direct impact, non-logistics factors also have an impact on the planning of the workshop layout facilities. For different production enterprises according to their own conditions constraints, the layout of the workshop is also different, so the influence factors on the mutual relationship between operating units are also different, such as whether the working environment is safe, whether the process is continuous, whether the material handling is easy to operate, whether the work contact is frequent, whether the working environment is hygienic, the similarity of the nature of the operation, the similarity of the type of machine, etc. The reason for the closeness of the influencing factors between the work units can then be given a relationship level for these closenesses and a non-logistic relationship correlation diagram can be drawn, as shown in Fig. 4.

3.3 Comprehensive Interrelationship Analysis

Combined with the actual situation of the production plant and the material handling and transport distance of the logistics relationship and non-logistics relationship involving work closeness, etc. have equal importance, take the ratio of the two as m:n = 1:1, the degree of closeness between operating unit i and operating unit j can be calculated according to Formula (1), MR_{ij} for logistics intensity, NR_{ij} for non-logistics intensity, m and n for the two accounted for the weight.

$$TR_{ij} = mMR_{ij} + nNR_{ij} \tag{1}$$

Each operating unit to the integrated relationship between the degree of closeness of the operating unit integrated interrelationship chart, see Fig. 5.

3.4 Initial Layout Scheme

In order to ensure the accuracy of the design scheme, the approximate location of each operating unit should be confirmed first, and then the specific location of each operating

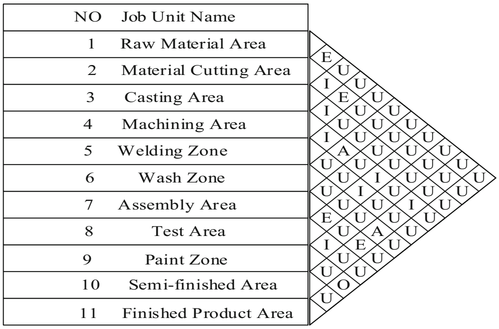

Fig. 5. Integrated interrelationship diagram of operational units

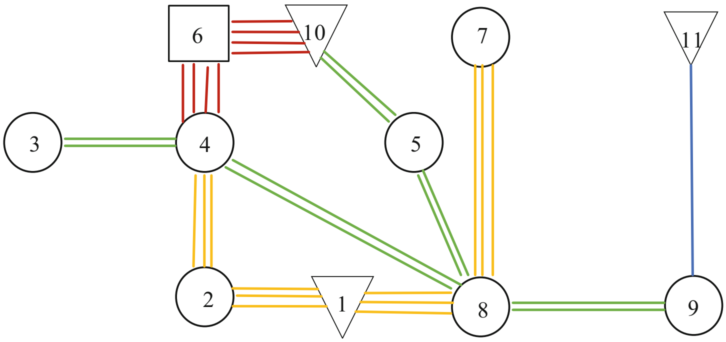

Fig. 6. Location-dependent diagram

unit should be determined according to the comprehensive proximity between each operating unit. When designing a layout drawing, the units that are closely connected should be designed in the center of the layout drawing; Synthesize units that are not closely related and distribute them at the edges of the layout diagram. According to the comprehensive closeness between the operating units, the position correlation diagram can be obtained by the line diagram method, as shown in Fig. 6, and the two initial schemes are shown in Figs. 7 and 8

4 Final Layout Scheme Based on Genetic Algorithm

4.1 Final Layout Scheme

In order to avoid the artificial subjectivity of the SLP method, the genetic algorithm is chosen to refine it. First, a single objective function is established with the objective function of minimising logistic costs and maximising non-logistic relationships. Then, the constraint generation is set and the solution obtained by the SLP method is brought to the initial population and the genetic algorithm is applied to solve for the better layout. According to the characteristics of the research object, the coding method is chosen as symbolic coding, and the coding chromosomes of the two optimised initial solutions

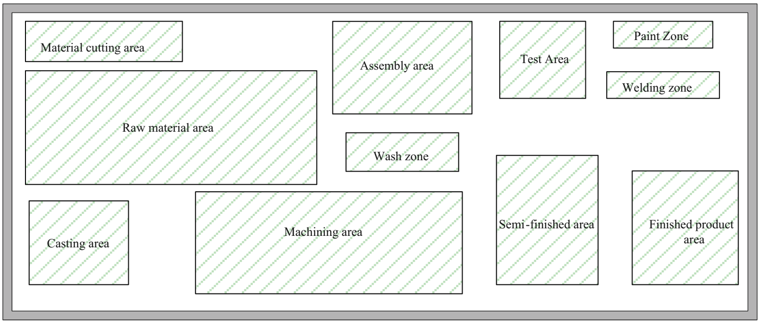

Fig. 7. Initial scenario one

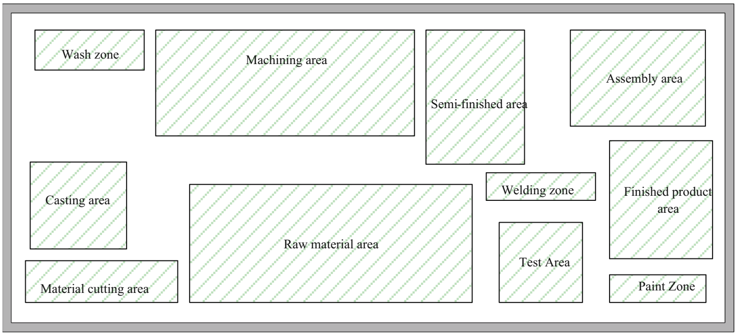

Fig. 8. Initial scenario two

obtained by the SLP method are {2, 1, 8, 9, 3, 4, 5, 6, 10, 7, 11}, {3, 4, 10, 11, 1, 6, 2, 7, 8, 9, 5}, and the method of exchange variation and selection of matching crossover is used, and the operator is finally chosen for the design of the roulette wheel method. After referring to a large amount of literature, the initial population size (pop-size) of 20–200 is appropriate in general, and the number of iterations (generation max) is between 50–500 range. Variation probability is generally taken between 0.01–0.1, crossover probability is generally chosen 0.3–0.99, combined with the actual problem of the workshop layout of the enterprise, so the initial population is (pop-size) 150, = 0.1, = 0.9, until the number of iterations is terminated.

The final run results and the final layout are shown in Figs. 9 and 10.

4.2 Analysis of Results

In order to check whether the final optimized layout has achieved effective improvement, the material transportation distance between relevant operating units before and after optimization is compared Table 3.

As can be seen from Table 3, the total route for material handling before optimisation was 809.5 m, and after optimisation the total route for material handling was 536 m,

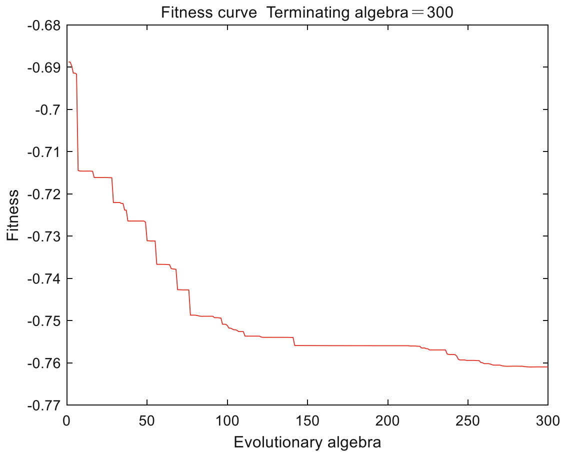

Fig. 9. Genetic algorithm operation process

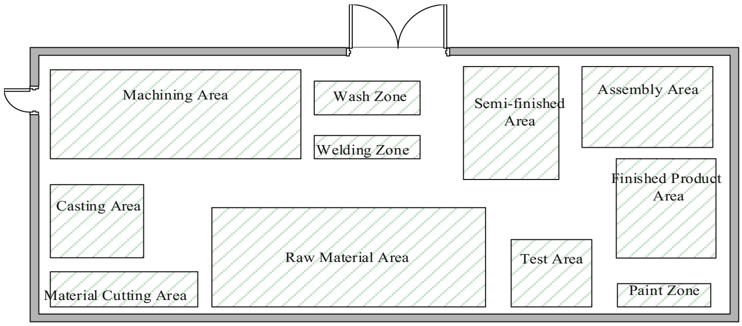

Fig. 10. Final optimization layout diagram

with an optimisation rate of 33.7%. The optimised material handling distance has been improved, improving efficiency and saving handling costs.

Table 3. Comparison table before and after optimization

No	Job Pair	Before Optimization (m)	After Optimization (m)
1	1-2	29	40
2	2-3	64	12.5
3	2-4	21	34
4	3-4	70	32.5
5	4-6	80	67
6	4-8	108	70
7	5-4	60.5	27.5
8	6-10	47	10
9	7-8	40	64
10	7-10	124	40
11	8-5	75	47.5
12	8-9	18.5	20.5
13	9-11	39	32
14	10-5	33.5	38.5
Total		809.5	536

5 Conclusion

In this paper, we applied SLP and genetic algorithm to optimize and improve the layout of the hydraulic cylinder workshop of Busines L. We proposed two optimized layout solutions and finally selected the optimal solution, which made the planning results more scientific. Taking the planning of hydraulic cylinder workshop facilities of Busines L as an example, the results show that the SLP genetic combination method has obvious advantages, which verifies the effectiveness of the process and provides guidance for the planning of the same type of workshop facilities.

References

1. Cao Yanghua, Kang Xiucui. Research on the improvement of workshop equipment arrangement based on SLP idea [J]. Modern Manufacturing Engineering, 2015(08):75–80. DOI: https://doi.org/10.16731/j.cnki.1671-3133.2015.08.011.
2. Gan Weihua, Xu Qihe, Huang Wen, Xie Donglian. Improvement of workshop facility layout of busines F based on SLP and production logistics [J]. Journal of East China Jiaotong University, 2015,32(03):55–62+102. DOI: https://doi.org/10.16749/j.cnki.jecjtu.2015.03.005.
3. Yun QQ, Liao S, Bai YX, et al. Transformation of plate stamping production line based on workspace layout. Modern Manufacturing Engineering, 2015(05): 12–16+136.
4. Ye Mujing, Zhou Gengui. Application of SLP and genetic algorithm combination in factory layout [J]. Journal of East China University of Science and Technology (Natural Science Edition), 2005(03):371–375. Doi: https://doi.org/10.14135/j.cnki.1006-3080.2005.03.024

5. Ai Dong. Optimization of dual-objective facility arrangement based on particle swarm algorithm [D]. Xi'an: Xi'an University of Architecture and Technology, 2015.
6. Zhou Jiaojiao. Research on optimization of workshop layout based on operational fatigue [D]. Chongqing: Chongqing University, 2016.
7. Liu J, Zhang H, He K and Jiang S. Multi-objective particle swarm optimization algorithm based on objective space division for the unequal-area facility layout problem [J]. Expert Systems with Applications, 2018, 102(JUL.):179–92.
8. Guan Chao, Zhang Zeqiang, Zhu Lixia, Mao Lili. A mixed integer nonlinear programming model and two-stage improved simulated annealing algorithm for the double aisle arrangement problem [J]. China Mechanical Engineering, 2019,30(08):975–983.
9. Wang L, Zhou YM, Mo YM, et al. Layout optimization of parts distribution centre for whole vehicle plants based on SLP method. Logistics Technology, 2017,36(02): 142–145+177.
10. Xu Xiu-Li, Lin Lan, Jiang Liang-Kui, Zhang Jian. Capacity allocation and layout integration optimization of equipment in flexible manufacturing shop. Machine Design and Research, 2019,35(05): 116–120+135