Optimisation Study of the Production Layout of the Fertiliser Plant of LM Company

Xinkun Huang[1,*], Jinyan Sang[2], Changrong Jin[3], Chao Tang[3], Luqi Yu[3], Wenjing Gong[3]
[1]Business School, Shandong University of Technology, Zibo, Shandong, China
[2]Department of Information Management and Information Systems, Shandong University of Technology, Zibo, Shandong, China
[3]Business School, Shandong University of Technology, Zibo, Shandong, China
**Corresponding Author.*

Abstract: Whether the layout of the production workshop is reasonable or not is directly related to the production efficiency, logistics efficiency and production cost of the product, which is an important link that cannot be ignored in modern industrial production. Based on the theory of system layout planning (SLP), a comprehensive research and problem analysis on the current situation of the workshop layout of a chemical fertilizer production company was carried out, and the relevance of each working area and various materials in the workshop was obtained; then the logistics and non-logistics relationships of each working area in the workshop were analysed by using the derived data; the comprehensive relationship correlation diagrams of each working area and the location correlation diagrams of each working area were made; finally, the logistics relationship correlation diagrams and the location correlation diagrams of each working area were made; finally, the logistics relationship diagrams of each working area were made. Then, we analyse the logistics relationship and non-logistics relationship of each working area in the workshop by using the obtained data; we make the comprehensive relationship correlation diagram of each working area and the location correlation diagram of each working area in the workshop; finally, we re-plan and design the whole workshop based on the SLP method. After the optimisation of the workshop, the logistics intensity is effectively reduced, the logistics efficiency and production efficiency are improved, and the production process is smoother; at the same time, the new layout also improves the utilisation rate of the production area and reduces the production cost.

Keywords: Fertiliser Plant; Workshop Layout Optimisation; System Layout Planning; Efficiency

1. Introductory

With the progress of agricultural modernisation, fertiliser production plants are facing high requirements in terms of productivity, cost control and environmental protection. LM Chemical Factory is a local fertiliser manufacturer mainly producing a wide range of fertilisers. In recent years, with the rapid development of agriculture, all kinds of agricultural products are coming out in endless streams and Shouguang, as a famous base for vegetable farming, the demand for fertiliser is only increasing, which has also brought LM Chemical Factory a Numerous problems, largely restricting its own development, which requires it to adjust and optimise its own fertilizer production plant, in order to improve production efficiency, reduce production costs and reduce environmental pollution.

In the field of workshop layout optimisation research, the theory of Systematic Layout Planning. SLP has been relatively mature and widely used [1-3]. SLP rationally plans the production layout by combing and analysing the logistic and non-logistic factors of the production process, so as to make the production smoother and the logistics more efficient, and to improve the economic efficiency [4]. SLP theory has been widely used in the fields of factories, hospitals, airports, libraries, campuses, catering services, shops, offices and laboratories, etc. It can be used for plant layout optimization, equipment placement and adjustment, logistics planning, and distribution route optimisation. Some foreign scholars have used the layout optimization scheme of SLP method to improve the production efficiency of their manufacturing enterprises and largely reduce the workshop production cost in the fields of welding lines of automobiles, manufacturing parts and suits of ships [5-7]; Sun Weiguang et al. also conducted qualitative and quantitative analysis of the workshop layout of the aviation conduit based on SLP and system simulation technology, which not only can achieve the reduction of the Transportation costs and improve the production efficiency of the target, but also for the new workshop process layout planning to provide valuable reference [8]; Qiu Yuzhou et al. SLP and genetic algorithms will be combined to establish the offshore wind turbine assembly workshop facilities layout mathematical model, the results of the study of discrete manufacturing enterprises to optimize the layout of the workshop facilities and reduce the cost of production of a certain reference significance [9]; A large number of studies have shown that, at present, the use of SLP theory to solve the problem of workshop layout has tended to mature, but the research needs to start from the practical, the need for a certain degree of research on the research object, the resulting data into a variety of algorithms for optimisation. Therefore, this paper will use SLP theory combined with genetic technology to conduct qualitative and quantitative analysis of the fertiliser workshop of LM enterprise, so as to make its workshop layout more reasonable.

2. LM Workshop Overview

2.1 Workshop Layout Status

Shouguang LM Chemical Co., Ltd. was established in 1990s, after years of development, it has become one of the important enterprises in China's fertiliser industry, which occupies an area of more than 5,000 acres and has an annual production capacity of millions of tonnes. It mainly focuses on the production of urea, with compound fertiliser, diammonium phosphate, potassium sulphate and some chemical raw material fertiliser products as secondary. It adopts coal to generate semi-water coal gas, and through the synthesis workshop to prepare synthetic ammonia, the purification workshop to make carbon dioxide through the compression workshop after pressurisation into the urea workshop, synthetic ammonia and carbon dioxide reaction to produce urea.

LM fertiliser workshop is mainly divided into ten parts: raw material warehouse, raw material processing workshop, reaction workshop, granulation workshop, drying workshop, cooling workshop, screening workshop, packaging workshop, quality inspection laboratory and finished product warehouse. The raw material warehouse is located near the entrance of the plant, mainly storing raw materials such as nitrogen, phosphorus, potassium, etc.; further inside are the granulation workshop and screening workshop, both of which are equipped with conveyor belts; next to them are the raw material treatment workshop and reaction workshop, and the reaction workshop is transported with the granulation workshop through pipelines because the reaction workshop is equipped with a number of reaction kettles, which can sublimate the coal raw materials into gas, and then transported to the granulation workshop through pipelines; at the easternmost side of the plant are the packaging workshop, quality inspection laboratory and finished product warehouse. In the easternmost part of the plant are the packing workshop, quality inspection laboratory and finished product warehouse, which are also transported by conveyor belt. The layout of the workshop is shown in Figure 1.

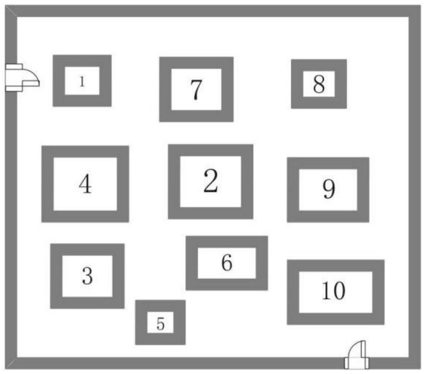

Figure 1. Layout of the Workshop

Take urea fertiliser production as an example, after obtaining raw materials from the warehouse, the required raw materials will be transported to the raw material processing workshop through the conveyor belt for crushing, screening and mixing of raw materials; then the crumbs will be transported to the reaction workshop through the conveyor belt to carry out a chemical reaction to generate basic fertiliser; it will be transported to the granulation workshop through the pipeline to be converted into particles; after that, it will be transported through the drying workshop, the cooling workshop, the screening workshop and the packaging workshop; finally, it can be transported to the finished product warehouse after quality inspection. After that, it will pass through drying workshop, cooling workshop, screening workshop and packaging workshop in turn; finally, it can be transported to the finished product warehouse after quality inspection. The specific workshop logistics transport route is shown in Figure 2.

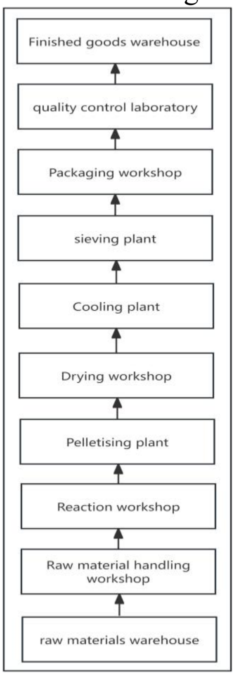

Figure 2. Fertiliser Production Flow Chart

2.2 Problems with LM Workshop Layout

At the initial stage of the construction of this fertiliser workshop, due to technical, site and financial constraints, there were more problems in a number of aspects involved, including logistics efficiency, space utilisation, safety and environmental protection:

(1) The distances between work units are too long and energy consumption is high when transported using equipment such as pipes and conveyors. This is especially true between workshops with large transport volumes, such as raw material warehouses and raw material handling workshops, where the straight-line distance between the two is long and can lead to cross-over and back-flow of material flow paths, which not only increases transport costs, but also makes the use of handling equipment less efficient.

(2) Low space utilisation. The layout of the workshops is more dispersed from workshop to workshop and there is unused space. For example, in the south-western part of the workshop, there is more empty space. This not only increases the cost of space, but also increases the distance of material handling and reduces production efficiency.

3. Calculation and Analysis Based on SLP Workshop Layout Parameters

3.1 System Layout Theory (SLP)

SLP method (Systematic Layout Planning), since 1961 by Chad Muth (Richard Muther) [10], has become one of the most respected and widely used methods in the field of shop floor layout design with its systematic and practicality. It provides a set of scientific decision-making tools for workshop layout through detailed quantitative and qualitative analyses [11].

The specific content of the SLP method is to get the required data related to the workshop layout through the in-depth research on the research object, determine the logistics intensity level between each work unit, then combine the non-logistics factors affecting the enterprise, weight the two, get the integrated relationship diagram to determine the specific location of the work unit, and then draw a more intuitive location-related diagram of the work unit, and formulate the preliminary workshop layout Optimisation plan. Specific implementation steps are shown in Figure 3. [12-15].

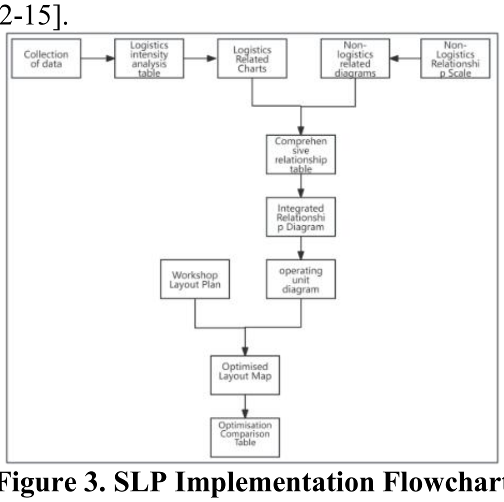

Figure 3. SLP Implementation Flowchart

3.2 Logistics Relationship Analysis

The logistics relationship describes how materials flow between different work areas, covering a wide range of material transport, processing and storage. Logistics intensity is an important indicator of resource consumption and environmental impact during the transport of fertilisers, and energy consumption (EI) is the amount of energy consumed during the transport of products within the workshop. We use energy consumption to replace logistics intensity, and in order to quantify the amount of logistics handling between work areas, we use Equation, which is calculated as follows:

$$\text{Total energy consumption (in kWh)} = \text{energy efficiency} \times \text{transport distance} \times \text{transport volume} \quad (1)$$

Through the systematic collation of the actual production data of the enterprise's production workshop, the LM fertiliser workshop uses 100 tonnes of coal as a benchmark. It is also known that the workshop mainly carries out transport work through pipelines and conveyor belts, and it is known that the energy consumption efficiency of conveyor belts is about 0.05kwh/m, and that of pipelines is about 0.0005kwh/m. After ascertaining the importance of each work area in logistics activities, we ranked the logistic intensities of these work areas. Subsequently, we compiled a logistics intensity grading table, which divides logistics intensity into five grades from high to low, namely A, E, I, O, U, in order to show the logistics needs and characteristics of each operation unit more intuitively. Here, "A" represents the highest level of logistics intensity, while "E" to "U" represent the levels of high, high, average and negligible logistics intensity respectively. Specifically, the corresponding ratios of logistics flows for these grades are: 40 per cent for grade "A", 30 per cent for grade "E", 20 per cent for grade "I", 20 per cent for grade "O" and 20 per cent for grade "B". Level "O" accounts for 10 per cent, while level "U" hardly carries any flow at all, with a proportion of 0 per cent. The logistics intensity of each work area is shown in table 1.

Table 1. Logistics Intensity Analysis Table

serial number	political line (e.g. right revisionist road)	Volume of transport (tonnes)	Transport distance (metres)	Energy consumption (kwh)	logistics intensity
1	1-2	100	200	1000	A
2	2-3	99	250	1237.5	A
3	3-4	67.716	100	3.3858	O
4	4-5	67.039	100	335.195	E
5	5-6	63.687	100	318.435	I
6	6-7	63.368	50	158.465	O
7	7-8	62.734	100	313.67	I
8	8-9	62.420	150	468.15	E
9	9-10	61.521	100	307.605	I

According to Table 1, the relationship between raw material warehouse and raw material processing workshop (1-2), raw material processing workshop and reaction workshop (2-3) is the closest, and the logistics intensity is A. Next, the relationship between granulation workshop and drying workshop (4-5), packaging workshop and quality inspection area is relatively close (8-9); the relationship between drying workshop and cooling workshop (5-6), screening workshop and packaging workshop (7-8), quality inspection area and finished product warehouse is large (9-10); the relationship between reaction workshop and granulation workshop (3-4), cooling workshop and screening workshop (6-7) is general, and there is no logistics relationship between operating units. The relationship between drying workshop and cooling workshop (5-6), sieving workshop and packaging workshop (7-8), quality inspection and finished product warehouse is large (9-10); the relationship between reaction workshop and granulation workshop (3-4), cooling workshop and sieving workshop (6-7) is general, and the logistics intensity level between the operating units that do not have logistics relationship is U, which is not in the scope of layout consideration. The specific logistics correlation diagram is shown in Figure 4.

3.3 Non-Logistic Relationship Analysis

In the layout planning of the production workshop, although the logistics factors have a crucial position, but in the actual production process, it is also affected by non-logistics factors other than the influence of material flow, so the existence of non-logistics factors should not be ignored. Through the detailed research on LM fertiliser workshop, the following non-logistic factors have been found: personnel contact, environmental requirements, work contact, management convenience and so on. Same as the above logistics factors, the logistics intensity is still divided into five levels from high to low, which are A, E, I, O, U. The logistics intensity of each work area is shown in Table 2.

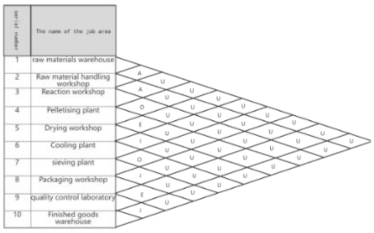

Figure 4. Logistics Relationship Correlation Diagram

Table 2. Non-Logistics Relationship Levels

hierarchy	A	E	I	O	U
Relationship strength	Absolutely important.	special importance	significant	usual	unimportant
proportions	2-5	3-10	4-15	10-25	45-80

After identifying several important non-logistics factors, the 10 work areas were analysed for non-logistics relationships based on the non-logistics relationship levels in Table 2. And through the field research, the non-logistic relationship correlation diagram was analysed and produced, as shown in Figure 5.

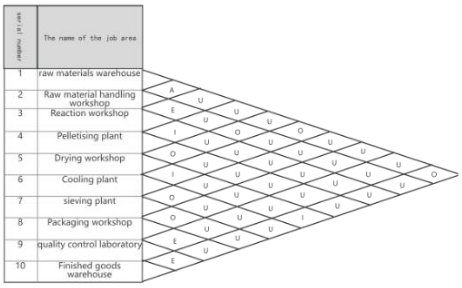

Figure 5. Non-Logistics Relationship Correlation Chart

3.4 Integrated Relationship Analysis

In shop floor layout planning, there are both logistical and non-logistical factors, both of which influence production to some degree. In order to accurately determine the comprehensive interrelationships between operating units, it is first necessary to consider the logistics and non-logistics factors in a unified manner. The setting of the weighted ratio needs to be fully integrated with the actual situation of the workshop and production needs to be considered comprehensively. In view of the fertiliser production process involves a large number of raw material input and output of finished products, logistics activities are very frequent, and the logistics efficiency directly affects the production efficiency and costs; in contrast, the direct impact of non-logistics relationships on production efficiency may be relatively small. Based on SLP theory:

(1) We set the weight of logistic and non-logistic relationships as 2:1; the specific formula is as in:

$$T_{ij}=m\times M_{ij}+n\times N_{ij} \quad (2)$$

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

(2) Quantify the intensity levels of logistic and non-logistic relationships as A=4, E=3, I=2, O=1, U=0.

According to the two principles of SLP theory, by assigning values to logistic and non-logistic relationships, the comprehensive relationship table of fertiliser production plant is obtained, as shown in Table 3.

Analysing Table 3, the ranks and values between the 12 job pairs, the integrated relationship between the job units is plotted, as shown in Figure 6.

Table 3 Integrated Interrelationships

political line (e.g. right revisionist road)	degree of intimacy				integrated relationship	
	Logistics relations (Weighted value: 2)		Non-logistic relations (Weighted value: 1)			
	hierarchy	mark	hierarchy	mark	hierarchy	mark
1-2	A	4	A	4	A	12

2-3	A	4	E	3	A	11
3-4	O	1	I	2	O	4
4-5	E	3	O	1	I	7
5-6	I	2	I	2	I	6
6-7	O	1	O	1	O	3
7-8	I	2	O	1	I	5
8-9	E	3	E	3	E	9
9-10	I	2	E	3	E	7
1-6	U	0	O	1	U	1
1-10	U	0	O	1	U	1
2-5	U	0	O	1	U	1
5-10	U	0	I	2	O	2

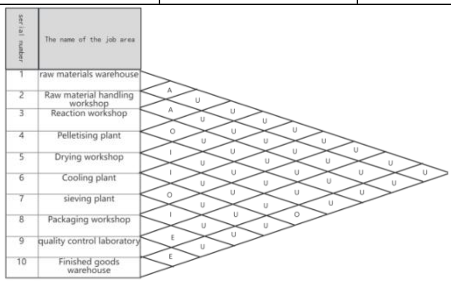

Figure 6. Integrated Relationship Correlation Chart

3.5 Improved Programme Design

When using the SLP theory to make a job location correlation diagram, the main objective of optimising the layout should be the main objective, such as minimising the material handling cost, maximising the space utilisation and improving the production efficiency. Therefore, the greater the logistic intensity between two work areas, the closer they should be distributed in the layout. Based on the scores of the integrated interrelationship table, the following order is obtained: 2, 9, 5, 3, 1, 8, 4, 6, 10, 7. Then, based on the integrated interrelationship table as well as the integrated ordering of the operating units, the location correlation diagram of the operating units is drawn. When drawing the operational location correlation diagram, pay attention to the use of different lines to indicate the relationship between the operational units, the greater the number of lines, the closer the interrelationship, the smaller the number, the more distant the relationship. The details are shown in Figure 7.

4. Improvement Programme Evaluation and Comparison of Effectiveness

4.1 Specific Improvement Programmes

The layout of the workshop is carried out after obtaining the optimal general location of each work unit based on the work unit location correlation diagram, combined with the initial layout of this workshop. This is shown in Figure 8.

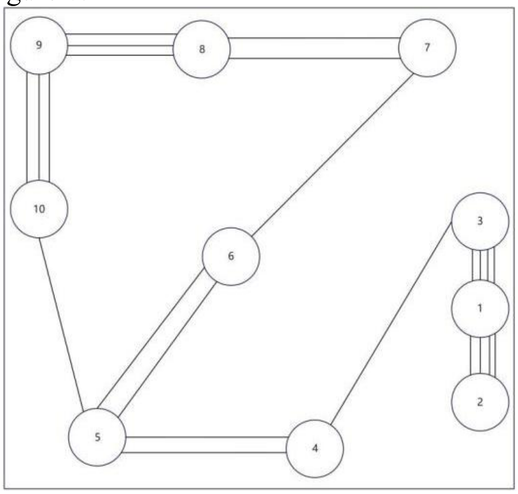

Figure 7. Map Relating to the Location of Operational Units

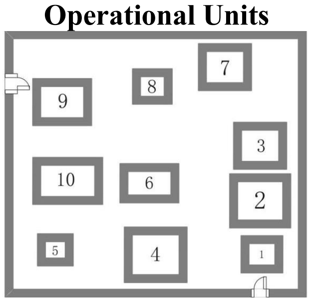

Figure 8. Optimised Layout Diagram

4.2 Optimised Solution Vs. Initial Layout

In the process of workshop layout optimisation, the comparison of the optimised solution with the initial layout is a key step in assessing the effectiveness of the improvement. In order to verify whether the optimised layout is more reasonable, quantitative analysis is carried out. It is assumed that one tonne of coal is used as raw material before and after the optimisation, and the transport distance between each work unit is measured to determine whether the layout is reasonable by comparing the logistics intensity before and after the optimisation. The specific comparison results are shown in Table 4 below.

According to Table 4, it can be seen that after the layout optimisation, except for the cooling workshop-screening workshop (6-7) which has become farther away, the transportation distance between each working area has become shorter, and accordingly the energy consumption between each unit has been reduced significantly. Especially, the energy consumption between raw material warehouse and raw material treatment workshop and between raw material treatment workshop and reaction workshop has become 250kwh and 247.5kwh from 1000kwh and 1237.5kwh, which is reduced by 75% and 80% respectively. The optimised workshop layout not only improves the production efficiency, but also reduces the production cost and improves the working environment, laying a solid foundation for the sustainable development of the enterprise.

Table 4. Comparison Table Before and After Optimisation

political line (e.g. right revisionist road)	pre-optimisation		post-optimisation	
	Transport distance (m)	Energy consumption (kwh)	Transport distance (m)	Energy consumption (kwh)
1-2	200	1000	50	250
2-3	250	1237.5	50	247.5
3-4	100	3.386	90	3.047
4-5	100	335.195	60	201.117
5-6	100	318.435	50	159.218
6-7	50	158.465	100	316.93
7-8	100	313.67	50	156.835
8-9	150	468.15	50	156.05
9-10	100	307.605	50	153.803
(grand) total	1150	4142.406	550	1644.5

5. Summaries

This paper takes the fertiliser workshop of LM Chemical Group as the research object, and optimizes the workshop layout based on the theory of system layout planning (SLP), combined with the analysis of the relationship between logistics and non-logistics. Firstly, this paper conducts a detailed research on the current situation of the fertiliser workshop of LM Company and analyses the problems existing in the existing layout. Then for these problems, the SLP theory is adopted to analyse the logistics relationship, non-logistics relationship and integrated logistics relationship. In the analysis of logistics relationship, this paper quantifies the energy consumption of material handling by calculating the logistics intensity between each work area; in the analysis of non-logistics relationship, this paper considers factors such as personnel connection, environmental requirements, work connection, etc., and draws a comprehensive relationship correlation diagram by weighting and integrating these non-logistics factors with logistics factors; finally, through the analysis of the comprehensive relationship, it determines the closeness between each work area and the workshop layout was re-planned accordingly. After the implementation of the optimisation scheme, the effectiveness of the optimisation scheme was verified by comparing the logistics intensity and energy consumption before and after the optimisation. The results show that the optimised layout significantly shortens the transport distance between the work areas and reduces the logistics intensity.

Overall, this paper proposes a set of practical workshop layout optimisation scheme through the application of SLP theory, combined with the analysis of logistics and non-logistics relationship. The optimised layout not only improves the production efficiency, reduces the production cost, but also reduces the environmental pollution, which lays a solid foundation for the sustainable development of the fertiliser workshop of LM Company, and is also of great significance for enhancing the competitiveness and sustainable development of the enterprise. The research methods and optimisation ideas in this paper also have important reference value for the optimisation of workshop layout in other similar enterprises.

References

[1] Jiang Y Y, Yang W Z, Gan R M J, et al. Optimisation study on the layout of prefabricated vegetable production workshop based on SLP and Levy flight genetic algorithm. Journal of Chongqing Gongshang University (Natural Science Edition), 2025: 1-12. http://kns.cnki.net/kcms/detail/50.1155.N.20250305.0932.002.html.

[2] Cao M K, Wang W J, Dai W. Research on logistics distribution centre layout model based on SLP and genetic algorithm. Industrial Engineering and Management, 2025, 1-22. http://kns.cnki.net/kcms/detail/31.1738.t.20250227.1109.002.html.

[3] Lin P J, Zhu Z Q, Guan C. A study on improving logistics efficiency of shoe factory workshop based on SLP method. China Storage and Transportation, 2025, (01): 106-107. DOI: 10.16301/j.cnki.cn12-1204/f.2025.01.072.

[4] Zheng G H, Liu P, Qian Y C, et al. Optimisation of workshop layout for key components of Fuxing rolling stock based on SLP. Railway Rolling Stock, 2023, 43 (04): 59-64.

[5] Hao J X, Bing H Y, Liang Z C, et al. Layout Optimization for Welding Workshop of Vehicle Door Based on SLP. Applied Mechanics and Materials, 2013, 459 (459-459): 356-360

[6] Wang T, Feng Y. Workshop Layout Optimation and Simulation Analysis Based on SLP: A Case Study//2023 4th International Conference on Management Science and Engineering Management (ICMSEM 2023). Atlantis Press, 2023: 1443-1453.

[7] Gong W. Optimization Study of the Production Layout in the Trouser Workshop of GR Company. Journal of Business and Marketing, 2024, 1 (3).

[8] Sun W Gu, Zu H S, Zhai F G, et al. Optimisation of aerospace catheter production line layout based on SLP and system simulation. Logistics Technology and Application, 2024, 29 (12): 172-179.

[9] Qiu Y Z, Xiang Y C, Fu L Z, et al. Optimisation of offshore wind turbine assembly plant facilities based on SLP and genetic algorithm. Shipbuilding Technology, 2024, 52 (05): 83-88.

[10]Qiu H, Xie R J, Liu Y. Optimisation Analysis of Reverse Logistics Recovery Point Layout on College Campus Based on SLP Method. Logistics Technology, 2022, 41(04): 32-39.

[11]Yao J J, Yang J. Research on process layout of large-scale reflux wind tunnel plant based on SLP method. China Equipment Engineering, 2024, (01): 101-103.

[12]Chen C X, Yuan Y, Chang Q S, et al. An analytical study on warehouse layout of small supermarket chains based on SLP. China-Arab Science and Technology Forum (in English and Chinese), 2022, (08): 79-84.

[13]Tan Q, Tang Q S, Xu H. Functional area layout of bus passenger station based on SLP method. Transportation Science and Economy, 2022, 24 (04): 16-22. DOI: 10.19348/j.cnki.issn1008-5696.2022.04.003.

[14]Zhang Y, Li Y L, Yin P, et al. Optimisation design of storage yard based on SLP logistics park. Neijiang Science and Technology, 2022, 43 (06): 40-41.

[15]Luo S F. Layout optimisation and simulation analysis of sorting centre layout of Company D based on SLP. Dalian Jiaotong University, 2022. DOI: 10.26990/d.cnki.gsltc.2022.000623.