Workshop Facility Layout Optimization Design Based on SLP and Flexsim

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***Abstract* — This paper takes the facility layout of the machining workshop as the research object, establishes the current layout model of the workshop and carries out the simulation through Flexsim simulation software, and finds out the unreasonable points; then, it applies the Systematic Layout Planning to carry out optimization design on the workshop layout, and does simulation on the improved layout model in Flexsim; according to the simulation result and SLP method, it comprehensively evaluates the rationality and feasibility of the improvement proposals from the quantitative and qualitative aspects.**

Keywords - facility layout; slp; flexsim; modeling; optimization

I. INTRODUCTION

With the rapid development of the lean production method, the manufacturing industry has already stepped to the lean production method, which raised higher requirements on the layout of the workshop. The facility layout has great impact on the production efficiency, production cost, logistics, etc. The statistical data indicates that, during the total production time when the material forms the product, the actual processing time only accounts for 10%-20%, and other time is consumed on the material transportation and waiting, which indicates that most cost is wasted on the carrying and waiting, which severely affects the improvement of the enterprise economic benefit[1]. Due to the complexity of the workshop layout, the way for obtaining the optimal proposal through traditionally establishing the mathematical model and through the experience not only is quite complex, but also cannot predict the layout effect in advance. Therefore, it is difficult to meet the demands of the modern production method. The Systematic Layout Planning (SLP) is an important qualitative research method of the facility planning, and it has been widely applied in various industries [2-3]. However, Flexsim can carry out entity modeling and simulation towards the workshop layout and obtain related result data, quantitatively analyze and evaluate the layout proposal, which is quite vivid, convenient and high-efficiency. This paper comprehensively utilizes SLP and Flexsim simulation software to perform optimization design for the workshop facilities, and reaches the goal of improving the production efficiency, making the logistics smooth, shortening the carrying distance, and efficiently applying the space[4-7].

II. PRODUCTION PROCESS AND CURRENT STATUS OF THE WORKSHOP LAYOUT

Some machining workshop mainly produces precise screw rod, and does mass production for a long term. This workshop contains raw material storage zone, machining equipment, thermal processing equipment, finished product storage area, etc. The carrying method during the production mainly adopts the forklift. The path design in the original workshop layout takes the moving of the carrying tools into the consideration. The width of the main path in the horizontal and vertical direction is enough for the bidirectional driving of the carrying tools. Besides, such tools can only be allowed to be driven in the path rather than between the equipment.

The processing of the precise screw rod is shown in Figure 1. It has many processing steps. The required machining equipment includes 4 lathes, a milling machine, a drilling machine, and 4 grinding machine. Measure the area where the workshop equipment is located, and draw the workshop facility layout and logistics flowing status diagram according to the processing steps, which is shown in Figure 2.

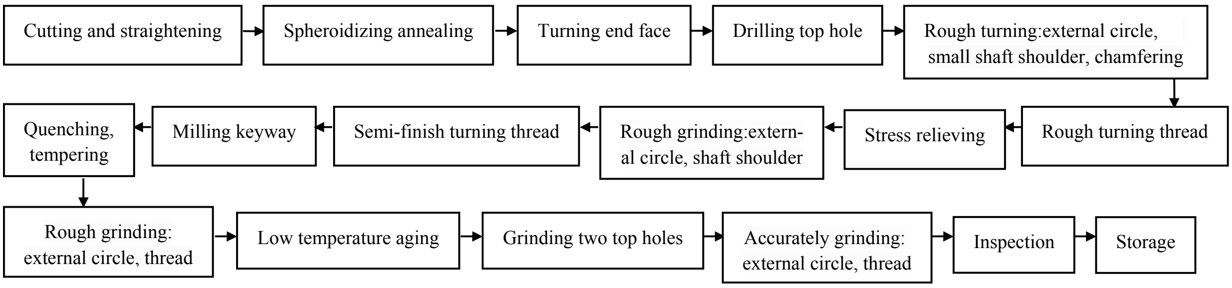

Figure 1. Processing Diagram of Precise Screw Rod

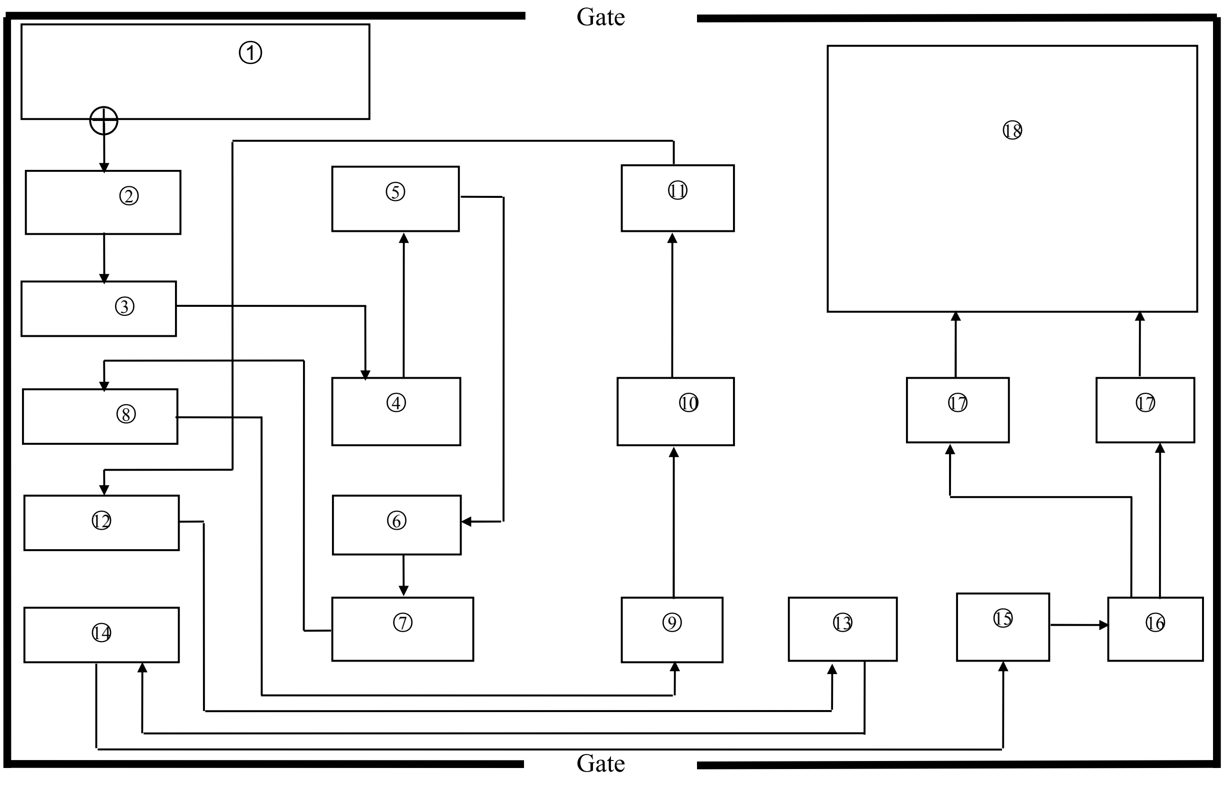

Figure 2. Workshop facility layout and current status of the logistics

Note: ①,②,③,④,……⑱ respectively represents Raw material storage zone, Cutting and straightening zone, Spheroidizing annealing zone, Lathe 1, Drilling machine, Lathe 2, Lathe 3, Stress reliev-ing zone, Grinding Machine 1, Lathe 4, Milling machine, Quenching tempering zone, Grinding Machine 2, Low temperature aging zone, Grinding Machine 3, Grinding Machine 4, Inspection zone, Finished product storage zone. Represents the beginning flowing direction of the raw material of the screw rod represents the production logistics routine of the screw rod. Below is same.

III. WORKSHOP LAYOUT MODELING AND SIMULATION RESULT ANALYSIS

A. *Establishment of Workshop Layout Model*

From Workshop Layout 2, there are totally 9 zones in the workshop, among which, 6 zones get involved in the processing production, and each zone has its own processing equipment and temporary storage zone. At present, the facilities in the workshop are replaced in Flexism entity. The generator is applied to replace the arrival of the raw material, and the buffer is applied to replace the storage zone of the raw material and work-in-process products, and the processor is to replace the finished product inspection; the storage rack replaces the finished product storage zone; the equipment of the machinery processing zone (lath, milling machine, grinding machine, and drilling machine) and the thermal processing zone are rep-
laced by a processor respectively. Therefore, it re-quires a generator, 17 buffers, 17 processors, a storage rack, and 5 forklifts. Drag these entities into Flexsim interface, rationally layout the position of each entity as per the workshop layout

and adjust its size, and then connect each entity as per the sequence of the processing steps of screw rod, and then obtain the simulation model. It is shown in Figure 3.

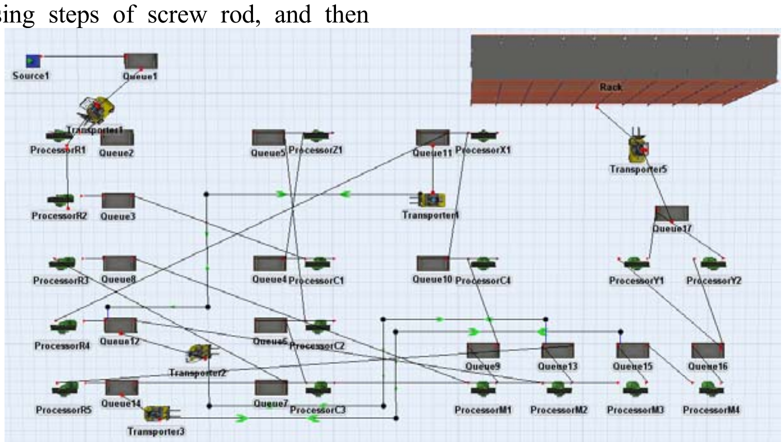

Figure 3. Workshop layout simulation model before improvement

B. Simulation Result Analysis

Set corresponding parameters for the model, click “reset”, “programming”, and “operating” in the interface of Flexsim. Then, the simulation model starts to run. When the simulation time reaches required 28,800s, it will stop automatically. Derive the simulation status report sheet, and obtain the data that is focused on in the status sheet, which is like Table 1. Due to the text length limitation, the simulation report sheet is not listed. However, it can be seen that 702 finished products are stored on the storage rack (one-day output).

TABLE I. SIMULATION RESULT STATUS BEFORE IMPROVEMENT

Name	Object	Idle%	Busy%	Blocked%
Cutting and straightening	ProcessorR1	9.21	91.79	15.35
Spheroidizing annealing	ProcessorR2	12.46	87.54	12.29
Turning end face	ProcessorC1	24.74	75.26	28.76
Drilling top hole	ProcessorZ1	26.38	73.62	23.12
Rough turning: external circle, small shaft shoulder, chamfering	ProcessorC2	17.27	82.73	0
Rough turning thread	ProcessorC3	11.26	88.74	0
Stress relieving	ProcessorR3	1.03	98.97	0
Rough grinding: external circle, shaft shoulder	ProcessorM1	19.75	80.25	0
Semi-finish turning thread	ProcessorC4	4.36	95.64	0
Milling keyway	ProcessorX1	16.39	83.61	0
Quenching, tempering	ProcessorR4	1.65	98.35	0
Rough grinding: external circle, thread	ProcessorM2	13.66	86.34	0
Low temperature aging	ProcessorR5	1.68	98.32	0
Grinding two top holes	ProcessorM3	19.69	80.31	0
Accurately grinding: external circle, thread	ProcessorM4	11.12	88.88	0
Inspection Platform 1	ProcessorY1	48.20	51.80	0
Inspection Platform 2	ProcessorY2	53.20	46.80	0
Forklift 1	Transporter1	2.49	97.51	0
Forklift 2	Transporter2	1.64	98.36	0
Forklift3	Transporter3	0.49	99.51	0
Forklift4	Transporter4	13.37	86.63	0
Forklift 5	Transporter5	2.61	97.39	0

From Table 1, it can be seen that:

1) The idle time of all processors is not zero, i.e. the utilization rate of all equipment does not reach the saturation status, while the cutting and straightening (Processor R1), spheroidizing annealing (Processor R2), turning end face (Processor C1), drilling top hole (Processor Z1) have some blocking, and the blocking rate of Processor C1 and Processor Z1 is higher than 20%. It indicates that the processing time of each process is not balance, or the temporary zone does not exist between the equipment or the capacity of the temporary zone is not enough.

2) The idle rate of 5 forklifts is relatively low. Except Forklift 4 reaches 13.37%, others do not exceed 3%, which shows that the utilization rate of the carrying tools is relatively high, and the arrangement of the tools in the workshop is relatively rational.

3) The utilization rate of 2 inspection devices in the finished product inspection zone is 51.8% and 46.8% respectively. The rate is quite low. Therefore, it is necessary to adjust the quantity of the inspection platform so as to improve the utilization rate of the inspection device.

Except the above conclusion obtained from the quantitative data of the simulation report, through the current status of the workshop layout, it can be seen that the logistics routines are complex and chaotic in the workshop, and even there is crossing and circuitous phenomenon, which leads to too long carrying routine, increasing of the carrying time and production logistics cost. In addition, the lathe, drilling machine and milling machine layout are not rationally planned, while the layout is al-so irrational, and the interval between the equipment in the thermal processing zone is too close, and the temporary zone of the work-in-process products is too small, and thus the same semi-finished products are stored in several storage zones, which are chaotic and affect the production efficiency.

IV. WORKSHOP FACILITY LAYOUT DESIGN BASED ON SLP

A. *Logistics and Non-logistics Analysis*

(1) Logistics strength grade

According to the production process of the screw rod, it is feasible to divide the involved region into 9 operating units. From the small number to big number orderly, there is the raw material storage zone, thermal processing zone, cutting and straightening zone, lathe zone, drilling machine zone, milling machine zone, grinding machine zone, finished product inspection zone and finished product storage zone.

Carry out relevance analysis on the logistics of the operating units, including the calculation and division of the logistics strength. The logistics strength is divided into five grades, i.e. A, E, I, O and U. It gradually decreases [1]. According to the process, carry out statistics on the gross logistics among the operating units involved in the material carrying, and then obtain the summary of the logistics strength among the operating units, which is shown in Table 2. In the table, the operating units that do not appear do not have the fixed logistics amount. Therefore, the logistics strength grade is U.

TABLE II. OPERATING UNIT LOGISTICS STRENGTH GRADE

Serial number	Logistics route	Logistics strength	Logistics strength grade
1	1-2	360	I
2	2-3	3240	A
3	2-4	2059.2	E
4	2-6	453.6	E
5	2-7	3760	A
6	4-5	217.2	I
7	4-6	117	O
8	4-7	165.6	O
9	7-8	720	E
10	8-9	720	E

(2) Logistics relevance table

According to the analysis on the logistics strength, it is feasible to obtain the logistics relevance table of the operating units, which is shown in Figure 4.

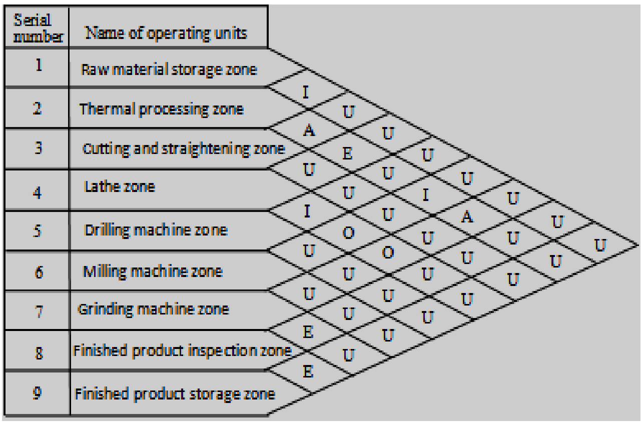

Figure 4. Logistics relevance

(3) Analysis on non-logistics relationship of the operating units

The logistics and non-logistics factors among the operating units in the workshop play equally roles in the facility layout of the workshop. Regarding the analysis on the non-logistics relevance of the operating units, firstly evaluate the reasons for the close relationship degree of the each operating unit (Table 3), and then adopt the same form as the logistics relevance table to establish non-logistics interrelation table of the operating unit (Figure 5).

TABLE III. REASONS FOR CLOSE RELATIONSHIP AMONG EACH OPERATING UNIT

No.	Reason
1	Continuity of the work process
2	Production service
3	Inferior-quality product carrying
4	Convenient management
5	Security
6	Vibration, noise, smoke
7	Inventory control
8	Information transmission

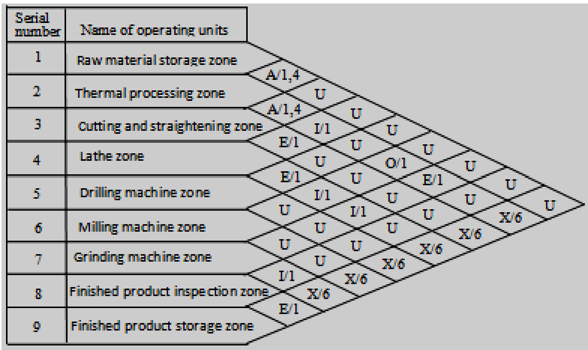

Figure 5. Non-logistic relevance of operating units

B. Analysis on the Comprehensive Interrelation of the Operating Units

According to the process and site status of the screw rod, the logistics influence is basically equal to the non-logistics influence. Set the weighting ratio of the logistics and non-logistics importance to be 1:1. Quantize the logistics strength grade and non-logistics grade. Select A=4, E=3, I=2, O=1, U=0, and X=-1. Merge the mutual relationship between the logistics and non-logistics; establish the comprehensive interrelation table as shown in Figure 6.

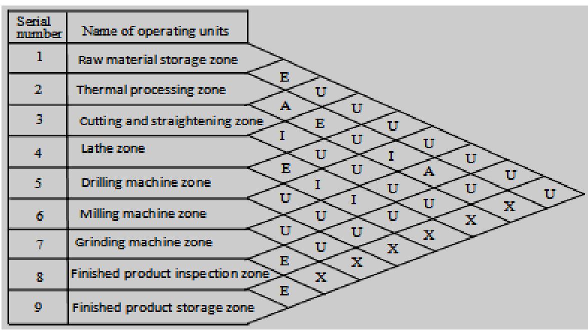

Figure 6. Comprehensive interrelation table of operating units

C. Location Correlation Diagram of the Operating Unit

During the drawing of the location correlation diagram of the operating unit, this paper does not take the area and geometrical shape of each unit into account. Through the comprehensive approaching degree among the units, arrange the relative location of each unit. The higher the correlation grade, the closer among the operating units will get, and the closer the distance will be. On the contrary, the distance will be further. That is to say, according to the sequence of the comprehensive approaching degree, if the score is higher, it is closer to the center; if the score is lower, it is in the edge. The calculation result of the comprehensive approaching degree of the workshop is shown in Table 4.

TABLE IV. SEQUENCING TABLE OF COMPREHENSIVE APPROACHING DEGREE

Code of operating unit	Comprehensive approaching degree	Sequencing
1	3	7
2	15	1
3	5	5
4	11	2
5	2	8
6	3	6
7	8	3
8	6	4
9	-3	9

According to the comprehensive approaching degree sequence table and the presentation method of the relationship grade of the operating units in the related table of the operating unit position, draw the location correlation diagram, which is shown in Figure 7.

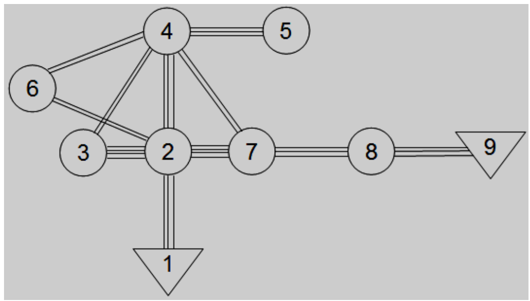

Figure 7. Correlation diagram of location of operating units

According to the location correlation diagram, feature and function of the operating units, fully utilize the sites, reduce the logistics and perform the humanization design. According to the actual status, adjust the design of the workshop facility layout and reduce the finished product inspection platform, and then optimize the layout.

V. Layout Model Simulation and Effect Evaluation after Improvement

A. Layout model simulation after improvement

Similarly, according to the way of establishing layout model in Flexsim before improvement, establish the improved workshop layout model chart as shown in Fig.6, set corresponding parameters, run the new simulation model, and obtain the simulation status report as shown in Table 8. From the simulation report, it can be seen that the finished product quantity stored on the storage rack is 760 pieces (one-day output).

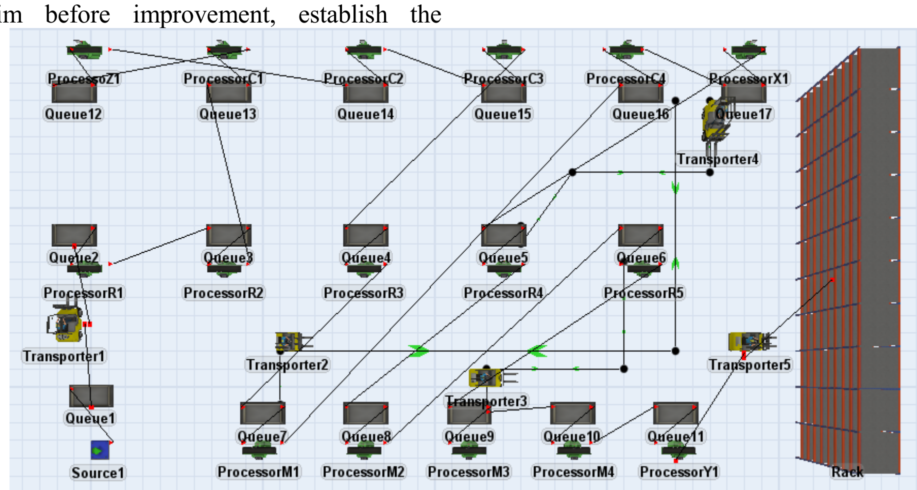

Figure 8. Workshop layout simulation model (after improvement)

TABLE V. SIMULATION RESULT STATUS AFTER IMPROVEMENT

Name	Object	Idle%	Busy%	Blocked%
Cutting and straightening	ProcessorR1	9.81	90.19	3.92
Spheroidizing annealing	ProcessorR2	10.16	89.84	0
Turning end face	ProcessorC1	21.35	78.65	9.62
Drilling top hole	ProcessorZ1	23.41	76.59	16.19
Rough turning: external circle, small shaft shoulder, chamfering	ProcessorC2	4.27	95.73	0
Rough turning thread	ProcessorC3	9.38	90.62	0
Stress relieving	ProcessorR3	2.03	97.97	0
Rough grinding: external circle, shaft shoulder	ProcessorM1	14.25	85.75	0
Semi-finish turning thread	ProcessorC4	0.47	99.53	0
Milling keyway	ProcessorX1	14.39	85.61	0
Quenching, tempering	ProcessorR4	1.62	98.38	0
Rough grinding: external circle, thread	ProcessorM2	12.32	87.68	0
Low temperature aging	ProcessorR5	1.63	98.37	0
Grinding two top holes	ProcessorM3	17.70	82.30	0
Accurately grinding: external circle, thread	ProcessorM4	11.05	88.95	0
Inspection Platform	ProcessorY1	11.50	88.50	0
Forklift 1	Transporter1	3.14	96.86	0
Forklift 2	Transporter2	1.67	98.33	0
Forklift3	Transporter3	0.47	99.53	0
Forklift4	Transporter4	17.88	82.12	0
Forklift 5	Transporter5	2.38	97.62	0

B. *Effect Evaluation*

Through the comparison on the Flexsim simulation result data before and after the improvement of the workshop layout, it can be seen that:

1) The production efficiency is improved. The data in the table indicates that, the utilization rate of each device after improvement has been improved in different degrees. In other words, the waiting time of the device is reduced. Moreover, the finished product quantity on the storage rack in the storage zone before improvement is 702 pieces, i.e. the daily output is 702 pieces. However, after improvement, it turns to be 760 pieces. It shows that the production efficiency of the workshop has been obviously improved.

2) The logistics in the workshop becomes smoother, and the temporary storage zone is properly arranged. After the improvement of the workshop layout, regarding the blocking rate of the processor, the blocking rate of Processor R1 is reduced from 15.35% to 3.92%, and that of Processor C1 and Processor Z1 is reduced from 28.76% to 9.62% and from 23.12% to 16.19% respectively. Thus, it can be seen that the blocking rate is obviously reduced. However, the blocking rate of Processor R2 is reduced from 12.29% to 0, i.e. the blocking does not exist. It indicates that the layout of the workshop logistics and work-in-process temporary storage zone become more reasonable, and the accumulation of the work-in-process products is reduced.

3) The utilization rate of the inspection devices is improved and the device cost is reduced. In the improvement proposal, reduce the device of the finished product inspection zone by one set, and the utilization rate of the last one set is 88.5%. The utilization rate is remarkably improved. Besides, a set of device is reduced, which decreases the production cost.

In addition, according to the pre-improvement and post-improvement workshop layout, it can be seen that the logistics routine becomes shorter after the improvement; the layout among the devices becomes neater and compacter; the path and work-in-process product temporary storage zone become larger, which fully and reasonably utilizes the space.

VI. CONCLUSION

Apply SLP and Flexsim simulation software to carry out reasonable adjustment and optimization design towards the workshop facility layout, realize the goal of reducing the logistics distance and logistics cost, and improving the production proficiency, and reducing the equipment cost. Besides, the workshop layout becomes more reasonable and neater, and the space resource is effectively utilized.

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