Layout optimization of signal control box production line based on SLP

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Abstract. Taking the production process of the signal control box as the research object, aiming at the problem of the unreasonable layout of the production line, the Systematic Layout Planning (SLP) method is used to obtain the relationship and position relationship diagrams between the various operation units, and the optimal layout plan is given, combined with the factory building Conditions and funding constraints, determined and implemented the production layout improvement plan, reduced the material handling distance, shortened the delivery cycle, and realized the rapid delivery of products.

1 Introduction

Q Company is a domestic large-scale air accessory equipment development and manufacturer, almost all domestic aircraft are equipped with Q companies to develop products. In 2018, the monthly average order volume of signal control boxes was 800 sets, while the actual output was 600 sets per month. Delivery quantity and delivery the cycle cannot meet customer needs, leading to constant complaints from customers. As orders continue to grow, customer satisfaction continues to decline, and there has been order loss.

The signal control box is assembled by a box body, an upper cover, a printed circuit board, connectors and cables, as shown in Figure 1.

Figure 1 Signal control box products

Through on-site observation, it is found that the signal control box production line has the following problems:

(1) The layout of the production line is unreasonable. The entire production line is three-dimensionally distributed on three floors of a factory building. During the production process, materials need to be transferred multiple times between the three floors. A lot of time is spent on material handling, resulting in low efficiency and prolonging product delivery cycles.

(2) The work flow setting is unreasonable. On-site observations revealed that there were unreasonable operation procedures such as waiting for materials in the

operation link and transferring materials back and forth between multiple processes. The limited working time was occupied by unreasonable operations and time wasted.

(3) The working hour quota is inaccurate. There is a deviation between the working hour quota and the actual operation time of the operator, and the quota cannot truly reflect the accurate time for the operator to complete the operation, resulting in inaccurate production scheduling and affecting production planning.

(4) The production line is not balanced. The unevenness of busy and idle work of the operators on the production line is more common, the operation process is not continuous, and the operation process stops frequently.

Aiming at the unreasonable production line layout problem found in the above analysis, this paper uses the Systematic Layout Planning (SLP) method to sort out and analyze the relationship between the operation units of the signal control box production line, and find the relationship between the various operation units. Under the dual constraints of plant conditions and funding, the layout was improved to increase product delivery.

2 Analysis of unreasonable production line layout and layout optimization

2.1 Analysis of unreasonable production line layout

The factory of Q company was built in 1955, mainly machining. The signal control box assembly line was transformed from a certain type of sensor assembly line. Because the production characteristics of the signal control box were not considered in depth, the location of the operating unit was unreasonable and the materials were located between 3 floors. Multiple transfers, long product production and logistics routes, long non-processing time for product transportation, measured

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signal control box material handling time 43min, handling distance 1347m, accounting for 19% of the total product processing time, becoming the main factor affecting product processing efficiency one. Figure 2 shows the layout of the signal control box production line before optimization.

Figure 2 Production layout before improvement

2.2 Production layout optimization plan and implementation

2.2.1 Analysis of production layout based on SLP method

The SLP method is the principle of the interaction between the work units in the entire production process in the process of layout scheme, and is not subject to the original layout to ensure that the final result is optimal^[1]. According to the SLP operation unit correlation analysis method, the relationship between the production line operation units is combed and analyzed^[2]. The production area of the signal control box includes the assembly area, the debugging area, the management office area, the technical center, the tool room, the inspection room, the finished product library, the packaging room, the tinning room, the parts library, the finished part library, the cleaning room, the cleaning room, the potting room and the For the 14 operating units in the three-proof coating room, according to the closeness of each operating unit and process, the degree of mutual interference, the frequency of contact, etc., the relationship between the operating units of the signal control box production line is drawn, as shown in Table 1^[3]. The degree of correlation between operating units is divided into six levels, marked with A, E, I, O, U, and X, as shown in Table 2^[4].

Table 1 Relevant relationship table of work unit

Operating unit	Proximity score					
	A	E	I	O	U	X
1. Parts library		7	2	8,13	3,4,5,6,9,10,11,12,14	—
2. Piece library	3,4	7	1,13	5,6,8,13	9,10,11,12,14	—
3. Enamel room	2,7		4,8	5,6,9,10,13	1,11,12,14	—
4. Cleaning room	2,7		3,8	5,6,9,10,13	1,11,12,14	—
5. Potting room	6,8,10	7,9		2,3,4,13	1,11,12,14	—
6. Three-proof coating room	5,10	7,8	9	2,3,4,13	1,11,12,14	—
7. Assembly area	3,4,8,10	1,2,5,6,9	11,14	12,13		—
8. Debug area	5,7	6,9	3,4,10,14	1,2,13	11,12	—
9. Tools Room		5,7,8	6,13	3,4,10	1,2,11,12, 14	—
10. Laboratory	5,6,7	11	8,13,14	3,4,9,12	1,2	—
11. Packing room	12	10	7	13,14	1,2,3,4,5,6,8,9	—
12. Finished product library	11			7,10,13,14	1,2,3,4,5,6,8,9	—
13. Management office area			9,10,14	1,2,3,4,5,6,7,8,11,12		—
14. Technology Center			7,8,10,13	11,12	1,2,3,4,5,6,9	—

Table 2 Relationship qualitative level analysis table

Relationship level	Need to be close	Reason number	Proximity reason
A	Absolutely ask to be close	1	High frequency of use
E	The relationship is very close and requires closeness	2	Frequency of use
I	Relationship is more important, need to be close	3	Low frequency of use

O	Normal relationship, generally close	4	High consulting traffic
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Table 2 Relationship qualitative level analysis table (Renewal)

Relationship level	Need to be close	Reason number	Proximity reason
U	The relationship is not important, and the distance is not limited	5	China consulting traffic
X	No need to approach	6	Low consulting traffic

Transform the close degree of each relevant work unit in Table 2 into the work unit correlation diagram, from $P=N(N-1)/2$, $N=14$ (number of work units), then $P=91$, a total of 91 operations the unit pairing, that is, 91 mutual relations, the mutual relation diagram between the work units is obtained [5], as shown in Figure 3:

Serial number	Operating unit name	
1	Parts library	
2	Piece library	
3	Enamel room	
4	Cleaning room	
5	Potting room	
6	Three-proof coating room	
7	Assembly area	
8	Debug area	
9	Tools Room	
10	Laboratory	
11	Packing room	
12	Finished product library	
13	Management office area	
14	Technology Center	

Figure 3 Diagram of the relationship between operating units

2.2.2 Improvement of production layout

According to the mutual relationship between the operating units, arrange the relative positions of the operating units, arrange the close relationship with the higher degree of closeness, and arrange the farther one with the lower degree of closeness [6]. First, according to the close relationship procedure, first draw the relationship diagram between A and E, then add the I relationship, and draw the rearrangement diagram after adding the I relationship, and then draw the rearrangement diagram after adding the relationship between O and U, Since there is no X relationship between the operation units of the signal control box production line, the relationship diagram drawn this time does not involve X, and finally the relationship diagram between the operation units of the signal control box production line is obtained, as shown in Figures 4, 5 and 6, with numbers 1-14 in the figure. Respectively represent the parts library, finished parts library, tinning room, cleaning room, potting room and three-proof coating room, assembly area, debugging area, tool room, inspection room, packaging room, finished product library, management office area, and technical center.

Figure 4 A and E relationship diagram

Figure 5 A, E, I relationship diagram

Figure 6 A, E, I, O, U relationship diagram

According to the position relationship diagram between the operating units, draw the optimal layout diagram of the signal control box production line, as shown in Figure 7.

Figure 7 The optimal layout of the production line

Due to the limitation of technical renovation funds and the limitation of the single-story area of the existing plant, the optimal layout of the production line cannot be implemented, and major renovations will inevitably lead to a substantial increase in expenditure costs. Through in-depth communication and discussion with workshop management personnel, under the principle of minimal changes to existing resources and minimal investment, the production activities are concentrated on the same floor as much as possible, and the material handling distance is minimized. The final improvement plan is formed: Plant 3 Technical transformation was implemented in the building, the production and processing activities were concentrated on the 3rd floor, the tin lining room, cleaning room, potting room and three-proof coating room on the 4th floor were moved to the 3rd floor, and the packaging room on the 1st floor was moved to the 3rd floor. In the inspection room, the inspection activities are included in the assembly work. The parts warehouse and finished parts warehouse on the 4th floor remain unchanged, and the original workshop office area and technical center on the 3rd floor are moved to the 4th floor. Expand the scale of the finished product warehouse on the first floor and transform the first floor into a special finished product warehouse for signal control boxes. The spatial layout of the production line after implementation of the improvement is shown in Figure 8.

Figure 8 Improved production layout

3 Improve results

According to the data collecting on-site, after improving the production layout of signal control box, the material handling distance and time are greatly reduced.

Main improvement benefit analysis:

- Shorten the product production cycle. After the improvement, the material handling time is 15 minutes, which is shortened by 65%. Increased product output within the same working hours (improved monthly output reached 680 sets).
- Shorten the material handling distance. The improved material handling distance is 447 meters, which is 67% shorter. According to the annual output of 8160 sets (680 sets $\times$ 12 months) of signal control boxes, the material handling distance can be reduced by 7,344 kilometers per year, and the material handling distance can be greatly shortened, which greatly reduces the work intensity of the operator and reduces the burden on the operator.
- The SLP method is used to optimize and improve the production layout, and the product delivery volume has been significantly improved, but it has not fully met customer needs. It is necessary to continuously improve the production line for problems such as unreasonable operation flow settings and unbalanced production lines, and finally achieve product delivery goals.

4 Conclusion

In this paper, the SLP method is used to solve the problem of signal control box production and delivery. Through comprehensive analysis and consideration of the relationship between the operating units of the production line, the layout optimization plan is obtained. After on-site implementation, a significant improvement effect has been achieved with a small amount of investment. The successful implementation of this plan provides a reference for the transformation of other product production lines of Q Company, and provides a way for many enterprises that lack funds to build new plants or whose original plants cannot expand their factories.

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