Optimization of distribution cabinet assembly process based on value stream mapping technology

Taozhu Feng1,a , Chunna Wang1,b*

1Management,Xi'an University of Science and Technology,Xi'an,Shanxi Province,China
aemail:fengtz1@xust.edu.cn,bemail:chunnawang99@126.com

Abstract: Aiming at the problems of excessive work-in-process, unbalanced production, and unreasonable production methods in the assembly process of S company's low-voltage switch gear A cabinet, the value stream mapping technology was used to propose an improvement plan for the assembly process, and finally the Flexsim simulation technology The optimization effect of the scheme was tested, and the simulation results showed that the production balance rate, delivery cycle, number of products in process, and fatigue strength of workers have all been effectively improved, which also reduced production costs for the company.

1. Preface

Value Stream Mapping Technology (VSM/A) is aimed at the production process of the product, studying the transfer of logistics and information flow, and depicting it with specific symbols and graphics, so that the entire complex value flow process is visualized, which is more intuitive Reflect the waste in the value stream, use the principle of lean production and industrial engineering methods to find out the cause and improve it, and then implement the improvement plan in actual production, so as to achieve the purpose of lean production [1].

So far, many scholars have studied the application of value stream mapping technology in manufacturing. Lulu Wang et al.optimized the assembly process from three aspects: information flow, supply chain, and process flow using value flow diagram analysis technology and process flow diagrams, and used Flexsim simulation software to verify [2]. Yanru Chang used the combination of value stream diagram and Flexsim simulation software to solve the problems of long production cycle, large inventory of products in process, and low balance rate in the assembly process of reducer [3]. Jose A et al. proposed a method based on PDCA (plan-execute-check-act) to improve the VSM research cycle, and applied it to the spiral rolling process, and achieved good results [4]. Adam B et al. verified that in addition to the value-added ratio that can be identified by traditional VSM, the use of Sus-VSM can also evaluate energy consumption, water use, raw material use, and social factors [5].

2. Enterprise status

S company is a manufacturer of electrical equipment. The company’s main switch cabinet types are type A and type B. As Type A is more cost-effective than type B, the company’s sales in the previous two years are calculated The data can also show that the sales volume of type A is more, so the type A production line is taken as the research object. Through on-site investigation of the type A production line, the relevant operation content of the main assembly line is analyzed, as shown in Table 1.
Table 1. Current production process data statistics table

| Order number | Process content          | Time available per shift/min | Production shifts | Number of operations | Daily demand/set | periodic time/min | production takt/min |
|--------------|--------------------------|------------------------------|-------------------|---------------------|------------------|-------------------|-------------------|
| 1            | Installation of row P    | 450                          | 1                 | 2                   | 13               | 31                | 15.5              |
| 2            | Installation of row N    | 450                          | 1                 | 3                   | 13               | 42                | 14                |
| 3            | Installation of door panels | 450                      | 1                 | 2                   | 13               | 30                | 15                |
| 4            | Wiring                   | 450                          | 1                 | 4                   | 13               | 50                | 12.5              |
| 5            | Electricity inspection   | 450                          | 1                 | 2                   | 13               | 80                | 40                |
| 6            | Final assembly           | 450                          | 1                 | 3                   | 13               | 27                | 9                 |

3. Mapping of value streams

3.1. Current Value Stream Map
For the collected production data of the main assembly line, the value flow and logistics status of the entire main assembly line are expressed by using special symbols and methods in the value flow diagram, and the current value flow diagram of the assembly process is drawn, as shown in Figure 1.

![Figure 1. Current value flow diagram of switch gear assembly line](image)

Calculate value stream evaluation indicators:
1) Value-added time (AT):

\[ AT = \sum_{j=1}^{k} CT_j = 310 + 150 + 60 + 390 + 160 + 55 = 1125 \text{ min} = 18.75h = 2.5D \]

2) Non-value-added time (UT):

\[ UT = \sum_{j=1}^{k} CT_j = 33 + 0.9 + 0.14 + 0.14 + 2.68 + 0.4 + 3.1 = 40.36D \]

3) Value-added ratio (I):

\[ I = \frac{AT}{AT + UT} \times 100\% = 5.8\% \]

It can be seen from the data that the non-value-added time of the assembly process is very high,
resulting in a very low value-added ratio. It shows that there is too much time waste in the assembly production line. It is necessary to start with the overall assembly process to optimize and improve, find out the reasons for the time waste, and formulate corresponding improvement plans, so as to reduce non-value-added time and improve time utilization.

3.2. Problem analysis

1) Unreasonable inventory of products in process

It can be seen from the current value flow chart that the two pre-assembly production lines of frame pre-assembly and drawer pre-assembly are island-like layouts relative to the main production line of switch gear\(^1\), resulting in the inability between the pre-assembly production line and the main production line. The continuous flow results in that the products of the pre-assembled production line do not correspond to the demand of the production process on the corresponding main production line, which in turn causes the inventory of products in the pre-assembled production line to increase, which increases inventory costs and labor costs.

2) Unbalanced production

The main production line of this product includes 6 production processes including installation of Row P, installation of Row N, installation of door panels, wiring, electricity inspection, and final assembly. By counting the sales volume of the product in the first six months of the company, it is predicted that the number of orders received for the product per month is 300 units, the monthly rated working day is 22 days, there is only one shift per day, and the available time per shift is 7.5 hours, then production The beat (TT) is:

\[
TT = \frac{\text{Available working hours per day}}{\text{Number of pieces required by customers per day}} = \frac{450}{13.6} = 33\text{min/pieces}
\]

\[
ER = \frac{\sum_{i=1}^{N} TT_i}{N \times TT_{RN}} \times 100\% = \frac{15.5 + 14 + 15 + 12.5 + 40 + 9}{6 \times 40} \times 100\% = 44.2\%
\]

It can be seen that the production line balance rate of the main production line is very low, and the power-on inspection process is the bottleneck process of the production line, which seriously restricts the production efficiency of the production line and needs to be improved in time.

3) Unreasonable production methods

Since the switch gear is specially designed according to the actual needs of customers, it is a non-standard product, so the order to the supplier is arranged after receiving the customer’s order, and the delivery cycle is 14 days, and the raw materials are supplied at one time. The warehouse cost is too high, and it also causes a great waste of time.

4. Optimization and improvement plan

1) Introduce continuous flow and supermarket pull system

From the value stream diagram, we can find that each process on the main production line has two or more repeated stations working in parallel, which is very easy to cause the problem of product accumulation. By setting FIFO between every two processes Channels can effectively control the inventory of work-in-process.

The pre-assembled production line and the main production line are not in the same production line due to the layout of the workshop. In order to minimize the WIP inventory between the pre-assembled production line and its corresponding production process, a supermarket pull system is introduced here. The finished product part is the part that is most closely connected with the customer. The pull system is introduced at the delivery point to improve the response sensitivity of the assembly line, avoid overproduction, and promote the flow of value stream throughout the production line. In order to solve the problem of the backlog of raw materials in warehousing, a stock supermarket is set up at the raw material purchase place to facilitate real-time control of the raw material inventory.

2) Production line balance
Through the current value stream map, it can be found that there is a large gap in the production cycle between each process, so it is necessary to balance the production cycle to shorten the product production cycle and improve product competitiveness. The wiring process is reduced by 1 station and 1 operator, the final assembly process is reduced by 2 stations and 2 operators, and the power-on inspection process is increased by 2 stations and 2 electricians. Qualified quality inspectors and the original 2 quality inspectors formed a 4-member FQC team to conduct power-on inspections on 4 switch gears at the same time. In this way, staff utilization can be greatly improved, bottleneck processes can be eliminated, and production capacity can be increased. The optimized production process data statistics table of the main assembly line is shown in Table 2. From the statistical data in Table 2.

Table 2. Improved production process data statistics table

| Order number | Process content | Time available per shift/min | Production shifts | Number of operations | Daily demand /set | periodic time/min | product takt/min |
|--------------|----------------|-------------------------------|------------------|---------------------|------------------|-----------------|-----------------|
| 1            | Installation of Row P | 450                           | 1                | 2                   | 13               | 31              | 15.5            |
| 2            | Installation of Row N  | 450                           | 1                | 3                   | 13               | 42              | 14              |
| 3            | Installation of door panels | 450                           | 1                | 2                   | 13               | 30              | 15              |
| 4            | Wiring            | 450                           | 1                | 3                   | 13               | 50              | 16.7            |
| 5            | Electricity inspection | 450                           | 1                | 4                   | 13               | 80              | 20              |
| 6            | Final assembly    | 450                           | 1                | 1                   | 13               | 27              | 27              |

The balance rate of the production line at this time: $ER = \frac{\sum_i TT_i \times 100\%}{N \times TT_{av}} \times 100\% = \frac{15.5 + 14 + 15 + 16.7 + 20 + 13.5}{6 \times 20} \times 100\% = 78.9\%$

3) Shorten the procurement period

Through internal communication, the purchasing department can shorten the monthly production procurement plan and production plan time from 7 days to two days, leaving more time for non-standard design and production, and in order to deal with the difference of non-standard orders After discussing with three major raw material suppliers in this province, it is possible to change the feeding once every half month to feeding once a week, which shortens the time waiting for the purchase of materials and saves costs.

5. Analysis of simulation results

5.1. Map the future value stream

Based on the current value flow diagram, and according to the optimization plan of the current main assembly line production process, draw the future value flow diagram of the assembly line, as shown in Figure 6.
By analyzing the specific data in the future value stream map, calculate the value-added time $AT$, non-value-added time $UT$ and the value-added ratio of the future value stream of the switch gear assembly. The calculation process according to the figure is as follows:

$$AT = \sum_{i=1}^{n} CT_i = 1.54D$$

$$UT = \sum_{i=1}^{n} CT_i = 11.42D$$

$$I = \frac{AT}{AT + UT} \times 100\% = 11.8\%$$

Compare the data before and after the improvement, as shown in Table 3.

Table 3. Comparison table before and after production line optimization

| Compare          | Non-value added Time/D | Value added ratio | Production balance rate | Production takt/min | Number of operations on the production line | Production cycle /D |
|------------------|------------------------|-------------------|-------------------------|---------------------|--------------------------------------------|--------------------|
| Before           | 40.36                  | 5.8%              | 44.2%                   | 40                  | 16                                         | 42.86              |
| After            | 11.42                  | 11.8%             | 78.9%                   | 27                  | 15                                         | 13.08              |
| Improvements rate/% | Decreased by 71.7 | Increased by 103.4 | Increased by 78.5 | Decreased by 32.5 | Decreased by 6.2 | Decreased by 69.5 |

5.2. Flexsim simulation verification

The production process of the assembly line after the implementation of the improvement plan was modeled and simulated with Flexsim simulation software, and the feasibility of the plan was verified through simulation data. The simulated model diagram is shown in Figure 7.
Figure 3. Simulation model diagram of the improved switch gear assembly line

The daily available production shift and time in the workshop is 450 min, the cycle of producing a switch gear is 261 min, and the production cycle is 20 min. Because the production cycle time is too large compared to the working time of one day, the result is not representative, so the running time of the model with regard to equipment utilization data is set to 4500 min, which is 10 working days. The running results of the simulation model are shown in Table 4.

Table 4. Simulation data results of workshop model

| Process name            | Equipment serial number | Equipment utilization | Equipment idle rate | Output | Average daily output |
|-------------------------|-------------------------|-----------------------|---------------------|--------|----------------------|
| Installation of Row P   | 1                       | 78.9%                 | 17.3%               | 114    | 11                   |
|                         | 2                       | 79.0%                 | 18.3%               | 114    | 11                   |
| Installation of Row N   | 1                       | 69.2%                 | 27.5%               | 74     | 7                    |
|                         | 2                       | 70.4%                 | 27.9%               | 74     | 7                    |
|                         | 3                       | 70.0%                 | 27.1%               | 74     | 7                    |
| Installation of door panels | 1                     | 72.6%                 | 24.8%               | 108    | 10                   |
|                         | 2                       | 73.2%                 | 22.8%               | 109    | 10                   |
| Wiring                  | 1                       | 80.0%                 | 16.6%               | 86     | 8                    |
|                         | 2                       | 78.0%                 | 17.3%               | 83     | 8                    |
|                         | 3                       | 79.2%                 | 18.5%               | 86     | 8                    |
| Electricity inspection  | 1                       | 90.0%                 | 0.42%               | 50     | 5                    |
|                         | 2                       | 91.6%                 | 0.49%               | 51     | 5                    |
|                         | 3                       | 91.0%                 | 0.53%               | 51     | 5                    |
| Final assembly          | 1                       | 88.2%                 | 53.6%               | 146    | 14                   |

It can be seen from Table 4 that the optimized production line can produce 14 switch gears per day, which can fully meet the daily order requirements of customers. After the workshop was improved, the number of products in progress was greatly reduced, free time was reserved for the front desk, and the fatigue strength of the workers was reduced. At the same time, the workshop inventory cost was saved, the production capacity was increased, and the feasibility of the plan was verified.

6. Conclusion
This paper takes the assembly process of the switch gear of S company as the research object, and improves the assembly process through the combination of value stream diagram technology analysis and Flexsim simulation technology. The simulation data shows the production balance rate, delivery
cycle, and number of products in the assembly line. As well as the fatigue strength of workers have been effectively improved, further verifying that the value stream mapping technology can provide an effective solution for traditional manufacturing to implement lean production.

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