Lean-Production Development in Shoemaking Industry: A Case Study

Jing Li¹,*, Kaifang Ding²,a, Yongming Zhu³

¹School of Management Engineering, Zhengzhou University, Zhengzhou, China
²School of Management, Jilin University, Changchun, China
³School of Management Engineering, Zhengzhou University, Zhengzhou, China

*Corresponding author e-mail: lijing_zzdx@163.com, *2823707511@qq.com

Abstract. It was generally found in most SMEs of China that there are many difficulties in on time delivery. Based on the study of bottlenecks theory and other relevant theories, we proposes an improvement model. First is the identification of the bottlenecks by pinpointing the relationship between customer demand and the actual capacity of the enterprise. Then is the analyze of the factors that restrict the bottleneck productivity and the construction of the corresponing ISM, and the improvement tools of IE is used to break through the bottlenecks. Once the bottlenecks drift out of the production chain, the use of VSM finally eliminates waste within the enterprise. Taking H as a case study, the value-added rate of the value stream increased by 5.84% through the application of the above improvement model.

1. Introduction

Lean thinking offers systematic approaches with optimal resources’ utilization via minimized waste in terms of time, money, etc. while satisfying clients’ demands [1]. The goal of lean manufacturing is to become highly responsive to customer demand while producing quality products in the most efficient and economical manner by reducing various waste in inventory, human effort, manufacturing space and time to market. In order to eliminate these wastes, the lean approach, which consists of a variety of tools, seeks to optimize the ‘value stream’, which are the processes by which service is delivered to the customer. Lean concepts have been a dominant paradigm in the manufacturing sector [2]. The manufacturing in China faces the challenge of having to improve production efficiency and product diversity in the context of increasingly high resource prices and complicated market environment [3]. The shoemaking, as a typical labor-intensive industry, not only faces the above difficulties, but also faces fierce competition from well-known foreign counterparts. The behindhand management system and unreasonable allocation of resources of SMEs engaged in shoemaking lead to low production efficiency, unstable product quality, messy work environment and factory accidents. Hence, it is vital to establish an approach to the improvement of assembly line of SMEs engaged in shoemaking.

The interaction between lean techniques and assembly line was investigated by several studies. However, these studies do not provide a clear understanding of the conditions that are required for these tools or techniques to enhance shoemaking efficiency. On the contrary, in this study, we propose an improved model to figure out the issues that delay in delivery, high inventory of work in process and unnecessary waste in shoemaking industry. Theory of Constrains (TOC), Interpretative Structural
Modeling (ISM) and Value Stream Mapping (VSM) were performed to investigate the current state of the value adding, non-value adding (not essential) and non-value adding (essential) activities involved in the shoemaking related tasks. To study the optimal production in SMEs, a shoemaking company named H was taken as the case. The TOC was used to identify the bottleneck, then the ISM about the factors that influence the bottleneck capacity was constructed. After optimizing the bottleneck process, the VSM was applied to eliminate the waste of the non-bottleneck process [4]. The paper is organized as follows: In the next section, the proposed improved methodology is explained in detail. The background of H and data collection are presented in Section 3. The results of H be applied by the proposed improved methodology are explained in Section 4. Conclusions are presented in Section 5.

2. The proposed methodology

In order to find and solve the bottleneck, eliminate non-value adding (not essential) activities and optimized non-value adding (essential) activities, we build an improvement model correspondingly, as shown in Figure 1. The brief explanations of the improvement model are as follows.

![Figure 1. The improvement model](image)

2.1. The Identification of bottleneck

The bottleneck refers to the process that the enterprise's actual capacity less than the market demand. Therefore, the first thing to do kaizen is to figure up the relationship between the actual capacity and the market demand [5]. About the collection of data, we take the customer demand and the actual capacity into account respectively. As for the customer demand, we can analyse the past shipment status through the indicators of shipments and on-time delivery rate, and we can consider the macroeconomic and industry life cycle to forecast the future market. Because of the comparability between market demand and actual production capacity, we use time as a uniform measure. For customer demand, the collected shipment and market forecast data are converted to pitch time.

2.2. Analysis of the factors restricting the bottleneck

In order to optimize the bottleneck, we use fishbone diagram to analyse the restricting factors of bottleneck scientifically. Then we present the complex relationship among factors by constructing the ISM model. The steps are as follows.
Step 1: Establish adjacency matrix. By means of questionnaires to inquiry the panel of experts, we can judge the relation among various factors, and deduce the adjacency matrix \( M \).

\[
m_{ij} = \begin{cases} 1, & S_i \text{ have direct impact on } S_j \\ 0, & S_i \text{ have no direct impact on } S_j \end{cases}
\]  

(1)

Step 2: The computation of reachability matrix and condemnation matrix by means of MATLAB. If it satisfy Eq. 2, the reachability matrix can be deduced.

\[
(M+I)^{n+1} = (M+I)^n \neq (M+I)^{n-1} \neq \cdots \neq (M+I)^1
\]  

(2)

Step 3: Construct the ISM by the iteration of reachable set, preemptive set, and common set.

2.3. The optimization of bottleneck

Some of the tools for bottleneck optimization derive from industrial engineering, such as the subdivision of working time, planned working time, operating time, actual operation time and value operation time of equipment, from which two major planned losses and six unplanned losses are discovered. Then we eliminate or reduce non-value-added time by the check table, man-machine operation analysis chart, 5W1H, etc. What’s more, we should adopt a correct attitude towards the stock of buffers. Once the bottleneck is broken, the stock of buffers should be cancelled because it will hinder the flow of value stream. Adding equipment or outsourcing processes also can help break bottlenecks.

2.4. The optimization of non-bottleneck

VSM is a well-known method proposed in the lean manufacturing approach in order to identify waste and improve performance [6]. The steps are as follows.

Step 1: Define value and identify waste in production.

Step 2: Draw the VSM of current status to discovery waste. Identify the value-added activities and non-value-added activities based on the current VSM.

Step 3: Eliminate the waste and redesign the value stream, the value-added rate of the value stream was increased correspondingly. We use 5W1H and ECRS to achieve balanced production and optimize production layout for reducing unnecessary movements.

Step 4: Eliminate waste further and implement a production model that is driven by customer demand (JIT).

Step 5: Draw the future VSM for the further improvement.

3. Case Study

3.1. The company profile

H located in Sui Country, Henan Province, China. With the registered capital of 150 million RMB, there are 64 production lines employing 20,000 workers. H mainly engaged in the production and operation of football shoes, skateboard shoes, basketball shoes, jogging shoes and casual shoes. And it is one of the main suppliers to 361 degree.

3.2. The process flow

The production of sneakers has three major sections: cutting, sewing and pre-forming. In detail, a pair of sneakers requires dozens of parts and hundreds of processes to complete as shown in Figure 2.
3.3. The current problem

By means of field research and the analysis of data, we discovered H has difficulties in on-time delivery. There are also a lot of waste in the production workshop. On-time delivery rate is an important indicator of customer satisfaction. It is the ratio of the number of orders that on time delivery to the total number of orders. With the customer demand and the number of orders grow, it is more difficult for H to deliver on time.

3.4. Data collection

Above all, we collected data that records past shipping and market forecasts. We concluded that the overall trend of customer demand is growing, which on on-time delivery of H becomes more important and pressing.

Then is the collection of the actual capacity’s data. The lack of production capacity in the process that manual operation can be fixed by overtime or temporary workers. Therefore, the actual capacity mainly depends on the key equipment which often turns into the bottleneck in most cases. Then is the calculation of the rate of comprehensive utilization of key equipment as shown in Table 1.

Finally, we calculated the actual production cycle in the key process based on the rate of comprehensive utilization of equipment in the key process and some formulas. As for other processes. We recorded the data by means of stopwatch, and eliminated the outlier. Then is the calculation of the actual production cycle in every process by the mean, and the allowances of different processes also be referenced [1].

According to the data collected previously, we drew the current VSM to help H discovery the problem and waste. The first step is to determine the form and frequency of shipments based on the customer demand, and the takt time calculated by corresponding formula. The second step is to draw the process flow, the material flow (WIP in the production line) and the information flow (daily production schedule). The third step is to define the value of every process (the value adding activities, non-value adding (not essential) activities and non-value adding (essential) activities), then the timeline of value stream is confirmed. The fourth step is to calculate the value-added ratio of value stream, concluding that the total value-added time is 520.47s, the production cycle is 840.112s, and the value-added ratio of value stream is 61.59%. From the Figure 3, we can located two key aspects for improvement. One is to improve the utilization rate of equipment in the computer sewing machine workshop, and the other is to break through the personnel capacity in the molding workshop.

Table 1. The rate of comprehensive utilization of equipment

| Key equipment     | the rate of availability | performance | quality index | the rate of comprehensive utilization of equipment |
|-------------------|---------------------------|-------------|---------------|--------------------------------------------------|
| YM Laser          | 80%                       | 99%         | 100%          | 74.2%                                            |
| Plant press machine | 90%                       | 100%        | 98.8%         | 88.42%                                           |
| JUKI-3020         | 60%                       | 100%        | 99.6%         | 59.76%                                           |
| JUKI-1510         | 90%                       | 100%        | 99.6%         | 89.64%                                           |
| High speed single | 85%                       | 90%         | 99%           | 75.74%                                           |
| Glue sprayer      | 80%                       | 90%         | 100%          | 72%                                              |
| Pneumatic eyelet  | 90%                       | 90%         | 100%          | 81%                                              |
| Heel-shaping      | 80%                       | 100%        | 100%          | 80%                                              |
| Toe cap mulling   | 95%                       | 100%        | 90%           | 85.5%                                            |
| Sander            | 60%                       | 90%         | 100%          | 54%                                              |
| Painting line pressure | 80%                       | 99%         | 100%          | 79.2%                                            |
| Pressing machine  | 80%                       | 100%        | 100%          | 80%                                              |
Because of the limitations of coverage, these diagrams don’t shown in this paper. Please contact the author if needed.

4. Result

4.1. Customer demand and actual capacity
To compare the customer demand and the actual capacity of process, we calculated by time unit, and replaced the actual capacity by the actual production cycle, and replaced the customer demand by takt time. Targeted the on time delivery, we calculate the takt time in different period of the future based on the past shipments and market forecasts.

4.2. Analysis of factors affecting bottleneck capacity
We can identify the location of bottlenecks from Figure 3, there are mainly the process of toe cap assembling, sole laying, and lacing. It is pressing to break through the above bottlenecks, because these will severely restrict the actual capacity with the increase of customer demand. We analysed the factors that restrict the productivity of bottlenecks in the first place. Taking the toe cap assembling as an example, we concluded the factors by means of the interview and field investigation of managers and operators as shown in Figure 4.
Step 1: Determine the direct relation among the factors that restrict the capacity of bottlenecks, and the adjacency matrix M was deduced based on the Equation 1. Fifteen factors that affecting the capacity of bottlenecks were analysed in terms of human, machine, material, method, and environment, and clearly shown in the fishbone diagram.

Step 2: Compute the reachability matrix a based on the Equation 2. Take the elements in the same row and column of matrix A as an element, we deducted the reachability matrix R through further reduction.

Step 3: According to the clear and stratified matrix R’, we constructed the ISM that affecting the capacity of bottlenecks as Figure 6.

4.3. Optimization of bottleneck process

The most direct factor affecting the capacity of bottlenecks is the comprehensive utilization of equipment, equipment performance, quality index and the batch quantity of equipment.

We can discovery the waste of waiting and failure shutdown by means of observing the computer vehicle JUKI-3020 and recording relevant data to improve the comprehensive utilization of equipment for the toe cap assembling.

Therefore, we focus on the waste of waiting and failure shutdown for improvement. On the one hand, drawing the diagram of the man-machine operation [2], the rate of equipment utilization currently is 40%. Considering the investment of fixed assets and human cost, we arrange two workers to operate a machine together and draw the improved diagram of the man-machine operation [3]. The rate of equipment utilization improved was 63.2%, which was 23.2% higher than before. On the other hand, we enhanced mold to double the batch quantity of equipment, and the rate of equipment utilization increased to 77.4%.

As for the processes of sole laying and lacing, we can balance time by increase the number of workers and establish the operation manual to standardize and program the processes for eliminating the influence of human.

After the implement of improvement, the bottlenecks drift out the production link and on time delivery can be accomplished.

4.4. Improvement of non-bottleneck process

The aspects that should be improved are as follows. Firstly, there are mass stock in the sewing workshop. Secondly, the process of heel-shaping existed the waste of movement. Thirdly, there are many defective products in the inspection after the process of sole milling. Fourthly, the processes of degumming inspection and sealant installation can be merged. As shown in Figure 6, after updating the VSM based on improvement, the total value-added time is 486.88s, and the productivity cycle is 726.68s, and the value-added rate of value stream is 67.43%.

Because of the limitations of coverage, these diagram doesn’t shown in this paper. Please contact the author if needed.
Figure 3. Current value stream mapping

Figure 4. The fishbone diagram
5. Conclusion

In order to solve the difficulties of on time delivery and high inventory, this paper propose an improvement model to help enterprises determine when to pay attention to constraints and waste. The key point of the process lies in the judgement about whether meet customer demand or not. If not satisfied, we should find out the bottlenecks that restrict the productivity of enterprises in the first
place, and analyse the affecting factors. Then is the construction of ISM to clarify and stratify the factors for the breakthrough of bottlenecks. Finally, the improvement tools of IE are used to improve the bottlenecks until these drift out of the production chain. When the improvement model was applied to H, on time delivery can be accomplished, and the value-added rate of value stream was increased by 5.84%. The theory is not unchangeable, and becomes more perfect and mature in constant practice. Enterprises should adhere to the spirit of continuous improvement in the changeable market conditions.

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