Scientific and Social Research, 2025, Volume 7, Issue 9
https://ojs.bbwpublisher.com/index.php/SSR
Online ISSN: 2981-9946
Print ISSN: 2661-4332

Optimization of Production Line Balance Based on IE Methods

Yujie Hao*

Business School, Shandong University of Technology, Zibo 255000, Shandong, China

**Author to whom correspondence should be addressed.*

Abstract: China's clothing industry occupies an important position in the manufacturing sector, with most enterprises being heavily reliant on the market, making both clothing styles and output subject to market demand. With the continuous economic development, consumers' requirements for clothing styles, functionality, and quality are increasing, prompting companies to urgently seek transformation and upgrades. This article focuses on the production process of the Type A shirt sewing workshop at Company ZY. Through research, it was found that this production line has issues such as low productivity, imbalanced production lines, and noticeable bottleneck processes. The study improved the balance of the production line based on the IE (Industrial Engineering) method, ultimately helping Company ZY enhance production efficiency and product quality, achieving a good level of balance for the clothing sewing production line. This also provides a practical case for production line optimization for the entire manufacturing industry. This article has significant practical implications for optimizing production processes in clothing enterprises and serves as a guiding reference for the study of optimization issues.

Keywords: Production line balance; IE methods; Production process optimization

Online publication: September 9, 2025

1. Introduction

As a traditional labor-intensive manufacturing industry, the clothing sector has historically focused on reducing production and labor costs, with little consideration given to upgrading production workshops and enterprise production management systems. With the widespread adoption of the internet and the rise of online sales channels, the clothing industry inevitably intersects with the internet, posing significant challenges to the production efficiency of traditional companies. At the same time, consumers' demands for personalized purchases are pushing the industry's production model toward small batches and customization, while most clothing companies in the country remain in traditional production models, struggling to meet the production scale required for modern manufacturing and the diverse individual needs of consumers. The COVID-19 pandemic in 2020 further delivered a tremendous blow to the physical industry, causing many small and medium-sized clothing enterprises to shut down or go out of business due to a slump in market demand triggered by the pandemic. Therefore, it is urgent to propose optimization plans for the production processes of clothing companies to cope with internal and external environmental pressures [1–4]. The core of the Industrial Engineering (IE) method lies in conducting a comprehensive evaluation of enterprises from the four dimensions of people, machines, processes, and environment, thus achieving optimal resource allocation and process optimization. Based on this logic, this paper takes the sewing production line of Company ZY as the research object, employing relevant IE methods to solve existing problems in the production line. The research goal is to enhance the balance rate of this production line, to help the business reduce costs and improve production efficiency [5–6]. This move can both strengthen Company ZY's competitiveness in an increasingly changing market environment and enhance its economic benefits while also providing a reference for other related manufacturing enterprises.

2. Analysis of the current situation and problems of the garment sewing production line of ZY Company

2.1. Current status of the production line

ZY Co., Ltd. was established in 1980 and is the first large modern joint-stock enterprise in China to have a complete production process of "spinning, weaving, printing, dyeing, cutting, sewing, and packaging", as well as an integrated model of "trade, industry, and agriculture." It has been ranked among the top 100 knitting enterprises in China for many years, and its products are exported to 24 countries and regions, including Japan, the United States, and the European Union, mainly providing processing services for domestic and foreign clothing companies, without involving its self-owned brand processing. As the market environment changes and consumer demands diversify, ZY Company faces multiple operational challenges: there are efficiency bottlenecks in the production process, the process design is unscientific and overly lengthy, leading to extended production cycles and increased operating costs; product quality fluctuates significantly, with a relatively high rate of defective products, negatively impacting brand image and customer satisfaction; production site management lacks systematic standards, and management systems are not well executed, further constraining the enhancement of production efficiency. Therefore, there is an urgent need to conduct a comprehensive optimization study of the company's production processes by diagnosing key issues in the existing process and formulating feasible optimization strategies in conjunction with market trends and changes in customer demands, in order to enhance the overall operational efficiency and market competitiveness of the enterprise.

This article selects the production process of the A-type shirt sewing workshop as the research object, which can be subdivided into 12 procedures, with a U-shaped layout for the production line.

Use the stopwatch method to measure the working times of each process on the production line.

(1) Conduct a continuous measurement of the work content for each process three times, and calculate the average to obtain the average observation time for each process.

(2) The workers selected for this observation are skilled employees, but due to a relatively chaotic working environment and long working hours each day, the selected average level assessment coefficient is set to 1. Considering factors such as employee concentration and fatigue, a comprehensive value of 10% is chosen as the allowance rate.

$$\text{Normal time} = \text{Average observation time} \times \text{Assessment coefficient} \quad (2\text{-}1)$$

Standard time = Normal time Relaxation time = Normal time × (1 + Relaxation rate) (2-2)

The standard working time before optimization is calculated based on formulas (2-1) and (2-2), as shown in **Table 1**.

Table 1. Standard time for the production process before optimization

Process content	Average observation time (s)	Expansion rate	Standard time (s)
Sew shoulders	61.03	10%	67.13
Make the placket	47.88	10%	52.67
Make pockets	63.75	10%	70.12
Make sleeves	85.76	10%	94.34
Sew sleeves	23.54	10%	25.89
Make the collar	49.70	10%	54.67
Make the under-collar	17.17	10%	18.89
Join the collar	48.88	10%	53.77
Sew the collar	73.84	10%	81.22
Make cuffs	93.07	10%	102.38
Sew cuffs	41.34	10%	45.47
Make collar buttons	35.08	10%	38.59

2.2. Production line balance analysis

The capacity of the production line is affected by the balance rate of the production line. If the balance rate of the production line is low, the capacity will also be relatively low. Therefore, optimizing the balance rate of the production line is very important for its capacity. By comparing the actual production capacity of the production line with the planned production capacity, one can identify the processes that affect production efficiency and optimize them. This involves reasonably allocating resources and optimizing the production process flow to ensure an average workload across all workstations on the production line. First, it is necessary to clarify the processing time for each workstation. Based on this, the reasons for the different times used by different workstations can be identified, and different optimization methods can be applied based on these reasons, ultimately aiming to improve the balance rate of the production line [7]. When analyzing the balance rate of the production line, it is necessary to use a lot of indicator data, such as the production line balance loss rate and smoothness index.

Production line balance rate $P=\frac{\sum_{i=1}^{n} T_i}{T_{max} \times S}$ (1)

Balance loss rate $IR = 1 -$ (2)

Smoothness index $SI = \sqrt{\frac{\sum_{i=1}^{n} (T_{max} - T_i)^2}{S}}$ (3)

According to formulas (2-3), (2-4), and (3-5), the production line balance rate (P) is calculated to be 61.52%, the balance loss rate (IR) is 38.48%, and the smoothness index (SI) is 54.60. It can be seen that the production line balance rate of ZY company's garment sewing workshop is poor, the efficiency of shirt production is low, and there is a significant potential for optimization and improvement of the production line.

2.3. Problems existing in the clothing production workshop

The production processes are unbalanced. In order to analyze the operation of

these 12 processes more intuitively, the standard times of each process of the A-type shirt sewing production line are depicted in a bar graph, as shown in **Figure 1**.

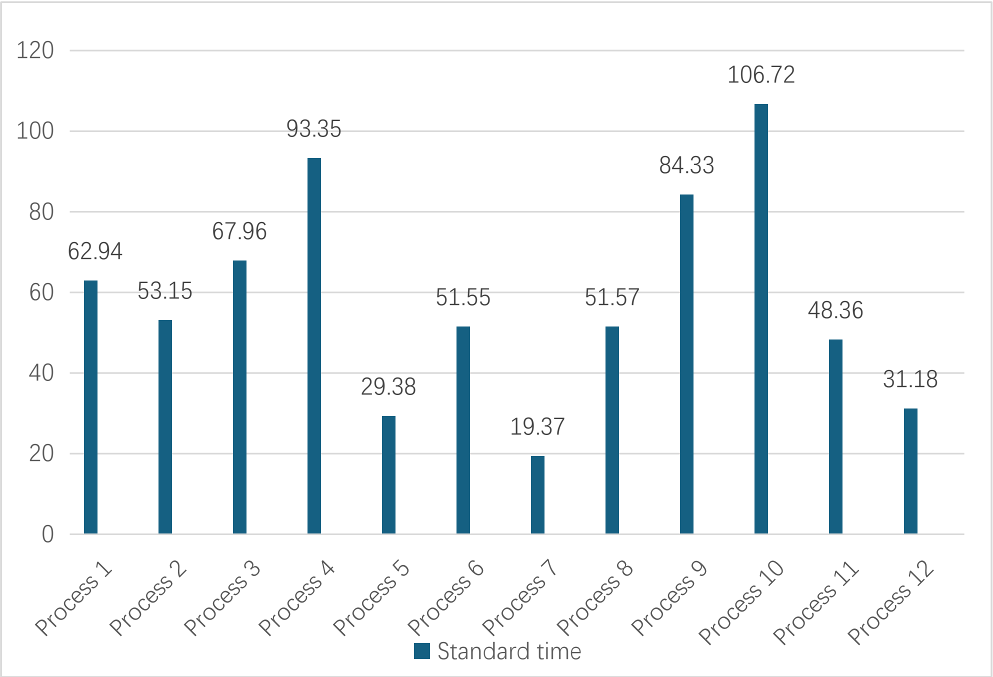

Figure 1. Standard time of each station

As shown in **Figure 1**, there is a significant difference in time consumption between workstations on the production line of this model shirt sewing workshop, with a clear bottleneck process, leading to idle production equipment and resources during the production process.

Insufficient production efficiency. ZY Company has an average daily market demand of 500 pieces of Type A shirts, and the workshop operates based on the legal working time of 8 hours per day. Therefore, the ideal production rhythm is: $8 \times 60 \times 60 \div 500 = 57.6$s. As shown in **Figure 1**, the time for the 5 processes exceeds the ideal production rhythm, and nearly half of the processes have severely low production efficiency.

Production management issues. The management of workshop production equipment is chaotic, and the sanitation conditions need improvement. The production site of ZY company is disorganized, and the layout of the production workshop is very unreasonable. Many old and damaged production equipment are placed haphazardly on the production site. As the core of enterprise production efficiency, the management and maintenance level of production equipment directly affects the production line's capacity. Due to the arbitrary placement of production equipment, the hygiene conditions of the workshop are poor, with a lot of dust, which greatly affects the working environment and the mental and physical health of the production staff. The placement of production materials is chaotic and unordered. In the process of garment production and processing, many production materials and tools are required, so toolboxes and material racks are often carelessly arranged by the staff. After using materials and tools, staff sometimes cannot return them to their places in time, resulting in increased time costs when looking for them for the next use. Some reworked products that do not pass quality inspection are piled together with ordinary work-in-progress items, and during the production process, they may need to be re-inspected because they cannot be distinguished, leading to unnecessary waste of production resources and costs.

3. Improvement of production line balancing based on the IE method

3.1. Bottleneck process improvement

The operational processes of Procedure 4 and Procedure 9 exhibit significant

complexity, as both procedures involve 5 operational steps, which is relatively more than other procedures, and require a high level of coordination between workers' hands. Long-term engagement in such high-difficulty coordinated operations can lead to muscle fatigue issues for workers. Therefore, by adding one more worker for each of Procedure 4 and Procedure 9, not only has the operational time and efficiency significantly improved, but it also ensures a smooth production process, reducing idle time for subsequent workers and equipment.

The standard operating procedures for the current two processes only outline the key steps and do not provide specific, detailed guidance on "motion optimization" and fatigue relief." In this case, non-standard operations largely do not adhere to the principles of motion economy, ultimately leading to an increase in workload for both processes and a decrease in overall efficiency of the production line; at the same time, the defect rate caused by operational deviations is also significantly higher than in other processes. To address this issue, a set of motion standards has been developed, which employees can refer to, and they can also choose their positions based on their own habits, thereby enhancing their collaboration under standard conditions.

3.2. Implement 6S management

6S management focuses on sorting, setting in order, cleaning, standardizing, and safety, centering on elements such as people, places, materials, and methods in the production site. It aims to create a clear and concise working environment through standardized management, achieving rational and efficient control of various production factors [8].

The specific implementation can be advanced step by step: the first step is "Sorting", which requires accurately distinguishing the actual use of items on the production site, keeping necessary items while clearing out surplus raw materials, tools, and other items from the site, thus reducing the space occupied by ineffective items from the source; the second step is "Arranging", where all items in the workplace are classified, organized, and fixed to specific locations, ensuring that each item has a designated storage area. This meticulous management not only significantly enhances the cleanliness of the work environment but also allows employees to easily know the storage locations of the required materials, and this visualization management is a key link in building an efficient and orderly work environment.

After completing the organization and arrangement, the next step is "cleaning", which means a thorough cleaning of the production site to continually maintain a tidy environment. Finally, through "literacy improvement", the authors enhance employees' professional quality, cultivate a good work attitude, and encourage employees to consciously adhere to company rules and regulations; at the same time, with "safety" as a premise, the authors guide employees to maintain a proactive working state, create a harmonious and relaxed work atmosphere, and thereby strengthen employees' sense of collective honor and promote the effective implementation of 6S management.

4. Analysis of the optimization effects of improved production line balancing

Table 2 below shows the standard working times for each procedure on the production line after improvement.

Table 2. Standard time for the production process after optimization

Process content	Average observation time (s)	Expansion rate	Standard time (s)
Sew shoulders	48.59	10%	53.45
Make the placket	47.88	10%	52.67
Make pockets	42.84	10%	47.12
Make sleeves	50.84	10%	55.92
Sew sleeves	44.87	10%	49.36
Make the collar	49.70	10%	54.67
Make the under-collar	40.33	10%	44.36
Join the collar	48.88	10%	53.77
Sew the collar	52.83	10%	57.11
Make cuffs	51.62	10%	56.78
Sew cuffs	41.34	10%	45.47
Make collar buttons	35.08	10%	38.59

From **Table 2** and **Figure 2**, it can be seen that the standard operation time for each process has been reduced to below the ideal cycle time, which means that the production line can complete the production of products within the stipulated time. The optimized production line's production capacity can meet market demand, which also aligns with our optimization principles. Using formulas (2-3) and (2-4), the study finds that the balance rate and balance loss rate of the improved production line are 86.56% and 13.52% respectively, with the balance rate of the production line increasing by 25.04%. This indicates that the improved production line has achieved a more ideal balance state.

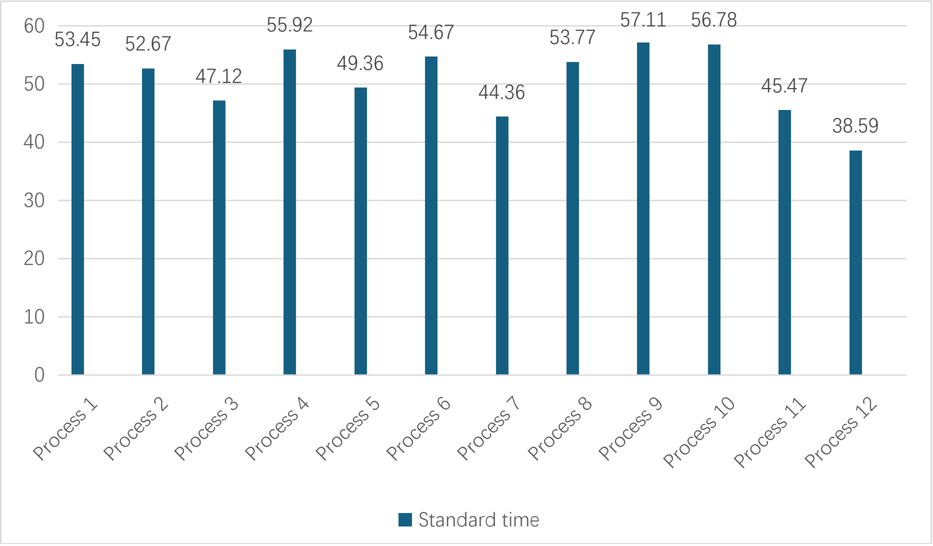

Figure 2. Standard time of each station

5. Conclusion

This article selects the clothing sewing production line of ZY Company as the research object, with the core goal of improving the line balance rate, and systematically optimizes the production line by introducing Industrial Engineering (IE) theories and methods. During the research process, targeted optimization improvement plans were formulated and implemented in response to key pain points such as the existing bottleneck processes in the production line (e.g., the complex operations of processes 4 and 9 mentioned earlier) and irregular on-site management. Ultimately, this not only significantly improved the balance rate and overall production capacity of the production line, laying a solid foundation for ZY Company's future development, but also provided a referable case for production line optimization practices in the entire manufacturing industry.

Disclosure statement

The author declares no conflict of interest.

References

[1] Ran L, Liu Y, 2023, Balancing Optimization of Motor Production Line Based on Industrial Engineering. EAI Endorsed Transactions on Industrial Networks and Intelligent Systems, 24(2): 5.

[2] Ozdemir R, Sarigol I, AlMutairi S, et al., 2021, Fuzzy Multi-Objective Model for Assembly Line Balancing with Ergonomic Risks Consideration. International Journal of Production Economics, 2021(239), 108118.

[3] Ortega-Jimenez JM, Dolgui A, Ivanov D, 2020, Hybridizations in Line Balancing Problems: A Comprehensive Review on Methodological Features. International Journal of Production Research, 58(11): 3329–3351.

[4] Nourmohammadi A, Eskandari H, Fathi M, 2019, Design of Stochastic Assembly Lines Considering Line Balancing and Part Feeding with Supermarkets. Engineering Optimization, 2019(1): 63–83.

[5] Syahputri K, Sari RM, Anizar, et al., 2018, Improving Assembly Line Balancing Using Moodie Young Methods on Dump Truck Production. IOP Conference Series: Materials Science and Engineering, 2018(288): 12090.

[6] Johnson RV, 1981, Assembly Line Balancing Algorithms: Computation Comparisons. The International Journal of Production Research, 19(3): 277–287.

[7] Zhao TT, 2021, Research on the Improvement of Production Line Balance Based on the IE Method. Journal of Qingdao University (Engineering and Technology Edition), 36(3): 88–92.

[8] Zhong QP, 2022, Research on the Improvement of the S Product Production Line of X Company Based on Lean Production, thesis, Nanchang University.