Mathematical Modeling and Algorithm Application
ISSN: 3006-0842 | Vol. 3, No. 3, 2024

Optimization and Simulation of Production Lines Based on Flexsim

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Abstract: With the rising labor cost in recent years, small and medium-sized enterprises are difficult to transform quickly due to the limitation of capital and technology, and thus their competitiveness in the industry becomes weaker. The simulation of production line by Flexsim software can analyze and improve the current situation of the production line at a relatively low cost, and provide corresponding data support for the optimization of the production line. This paper takes the wooden furniture production line of company A as an example, based on the combination of "IE" method and Flexsim simulation software to optimize the problems and bottlenecks in the production system, and uses Flexsim software to verify the simulation and put forward the production line optimization plan. Comparing the simulation data, it can be found that the balance rate of the production line of Company A has been improved by 46.71%, which effectively improves the efficiency of the production line, and provides a certain reference for the optimization of the wooden furniture production line of other small and medium-sized enterprises.

Keywords: Production line; Flexsim; Balance Optimization

1. Introduction

Under the wave of manufacturing 4.0, the competition between the manufacturing industry is becoming more and more intense, the transformation and upgrading of the production line is imminent, wooden furniture is the main choice in China's furniture industry, in the relevant market research shows that 65.61% of consumers in the choice of furniture will choose wooden furniture [1], at the same time in recent years, in the consumer's choice of furniture will pay more attention to personalized choices, and now Finished wooden furniture on the market compared to the past less, and customized wooden furniture compared to the past more, so now companies usually use a variety of small batch production. Small and medium-sized custom wooden furniture workshop overall automation and intelligence level is low, the production of various processes are dependent on manual operation, so the existing artificial operation of the staff optimization and adjustment is for wooden furniture enterprise production line is a more reasonable way to optimize. In the production line processing process, production efficiency and product quality may be problems, mainly due to the workshop layout of the irrational, personnel operating errors and so on, resulting in production line imbalance, thus bringing many problems to the production management. By optimizing the balance of the production line, we can improve the efficiency of the production line to cope with the many problems that may arise in the production process.

This paper takes the plate production line of company A as an example, applies industrial engineering knowledge, uses the simulation modeling tool Flexsim to re-plan the layout of company A's production line, analyzes the bottleneck process of the production line, and combines the results of the simulation to put forward a set of improvement plans applicable to company A, so as to improve the balance of the production line. And according to this, it provides a certain optimization basis for small and medium-sized wooden furniture customization companies.

2. Literature Review

There are research status of optimization of production balance using modeling simulation, foreign countries mainly established the model of the production line, and deduce and optimize the production line by quantitative way. KAgpak and HGokgen analyzed the situation of two limited resources of the production line, and found the solution and optimized it by modeling method [2].BiottoC et al. outlined the theory of the design of the production line, and emphasized the fact that in the production should focus on elements such as production beat and process flow to improve the efficiency of the production line [3].A. GCampos et al. proposed a new production management model by combining lean production and Johnson scheduling method and modeled it accordingly, which has achieved significant results. The model succeeded in reducing setup time, improving machine availability and reducing delivery delays, which very significantly improved the production line efficiency [4]. Neungmatcha et al. took the vehicle headlight production line as the object of study and used simulation software to build a simulation model and optimized the process using the ECRS principle, which led to a great reduction in the production cycle time of the product and improved the production efficiency [5]

In China, simulation is mainly used to evaluate and analyze the production system, and then optimize the process and personnel allocation through industrial engineering methods to support the optimization of production line balance. Song Ying et al. used Flexsim software to simulate the single-piece assembly line of T-shirt, and by optimizing the time spent on bottleneck processes, they successfully increased the production balance rate from 80.4% to 95.3% [6]. Huang Yunxiao et al. explored the optimization of production line according to the visual perspective, simulated the operation of production line using visual simulation software modeling, constructed the process flow program to capture the basic

information, and optimized the production line [7]. Hongmin Li et al. used Cadwork simulation platform to simulate the design of a typical arch, and finally improved the efficiency of arch processing through digital processing [8]. With the help of Flexsim software, Sun Yinghui and Du Jinsong conducted a study on the garment single-piece production line, and finally simulation modeling analyzed the optimization scheme, which successfully improved the production efficiency of the production line [9]. Simulation optimization is a very important means in the field of industrial engineering, through simulation optimization, we can more intuitively see the problems encountered in industrial engineering. Moreover, in production line optimization, by using simulation model to analyze the process, we can find out the bottleneck process more easily and propose the optimization plan accordingly, which improves the reliability of our proposed plan.

A study on customized wooden furniture production line found that the current stage of production is mainly used to unify multiple orders, and then classification planning, followed by unified production, the formation of a certain product group [10], Wang Lina et al. found that small and medium-sized enterprises in the customized furniture production plant of the level of automation and intelligence are lower, the process is more dependent on the operator [11]. Considering the limited cost of most small and medium-sized enterprises, it is more economical to re-plan the personnel and re-arrange the layout than to replace the equipment and re-plan the plant [12].

3. Analysis of the current situation

3.1. Production line survey

Company A is a small wooden furniture processing company, the main business scope includes the customized production of wooden furniture, the process is mainly by the consumer in a certain range of options, according to the consumer's different choices, you can choose glossy paint and matte paint, in the choice of cabinets, the consumer also has a certain right to choose, after these choices to place an order, the company is responsible for the whole batch of the order after the order of the production of the whole process is relatively standardized. The entire production process is relatively standardized, and the products produced by Company A are mainly furniture panels and door panels of various sizes, and the production process is divided into wood milling, oil milling, priming, oil milling, top coating, processing center, sorting, inspection and packaging. The operation time is an important data to measure the balance rate of the production line, this paper adopts the stopwatch time measurement method to measure the time of each process of producing a batch of customized panels in Company A (this batch includes 32 standard panels and 4 customized panels), collects and analyzes the time of its operation according to this batch of products, and conducts on-site investigation of the collective situation of the production line of Company A, combining with the industrial engineering method for the site situation to be analysis and optimization.

3.2. Measurement of production operating time

Starting from the actual situation in the workshop of Company A, the process sequence, the number of personnel, and the number of production equipment in the workshop were first investigated. The stopwatch method was applied to measure the whole process procedure, and the number of observations was set to 5 times. After the measurement of all processes, the abnormal data are eliminated, and then the triple standard deviation method is used to process the data, and the following is the specific processing method:

(1) Calculate the mean of N samples $\bar{X}$

$$\bar{X} = \frac{X_1+X_2+X_3+\cdots+X_n}{N} \tag{1}$$

(2) Calculation of standard deviation δ

$$\delta = \sqrt{\frac{\left(X_i - \bar{X}\right)^2}{N}} = \sqrt{\frac{\left(X_1 - \bar{X}\right)^2 + \left(X_2 - \bar{X}\right)^2 + \left(X_3 - \bar{X}\right)^2 + \cdots + \left(X_N - \bar{X}\right)^2}{N}} \tag{2}$$

(3) Calculation of upper limit UCL and lower limit LCL

$$\begin{aligned} UCL &= \bar{X} + 3\delta \\ LCL &= \bar{X} - 3\delta \end{aligned} \tag{3}$$

Where UCL refers to the upper limit of normal data and LCL refers to the lower limit of normal data. A set of observations is said to be free of outliers if they are all within the interval (UCL, LCL), and if there exists data outside this interval, the data is deleted.

Take the first process of "wood grinding" as an example to check whether there are outliers in the observed data, and Table 1 shows the judgment situation.

Table 1 Time required for the "wood grinding" process

	1	2	3	4	5
Observation time	42.8	45.6	43.1	47.9	46.6
average value	δ	UCL	LCL		outlier
45	2.0	51.0	39.0		not have

After that, the normal time is determined, and the normal time of the process is found according to "normal time = observation time * evaluation factor". After determining the normal time of the process, it is necessary to consider the stopping time of the workers, which is also called the grace time. Usually we give the wood processing plant 5% of the grace time. Then the standard working hours calculation formula is

$$T = T' \times (1 + k) \tag{4}$$

Where$T$ is the standard time (s),T' is the normal time (s), k is the relaxation rate, according to which we can get the standard time of each process, as shown in Table 2 below

Table 2 Production line processes and their times

serial number	Process name	Normal working hours/min	Standard working hours/min
1	**wood mill**	**45**	**47.3**
2	**oil mill**	**13.4**	**14.1**
3	**primers**	**6.1**	**6.4**
4	**oil mill**	**7.9**	**8.3**
5	**top coat**	**11.4**	**12.0**
6	**machining center**	**22.9**	**24.0**
7	**sorters**	**7.9**	**8.3**
8	**Inspection Packaging**	**22.6**	**23.7**
add up the total		**137.2**	**144.1**

3.3. Production line balance analysis

Production line balance is a technical means and method to balance the capacity of each process by analyzing the load of each process in the production line and adjusting the load distribution between each process. To measure the balance of the production line, usually using the production line balance rate (E), production line balance loss rate (D) and production line smoothing index (S) and other indicators for evaluation, the formula is as follows:

$$E = \frac{T_{总}}{n \times C_T} \times 100\% \tag{5}$$

$$D = \frac{n \times C_T - T_{\mathbb{Q}}}{n \times C_T} = 1 - E \tag{6}$$

$$S = \sqrt{\frac{\sum_{i=1}^{n} (C_T - T_i)^2}{n}} \tag{7}$$

Where, T_A is the total time of the job, n is the number of processes, C_T is the beat of the production line, and T_i is the job time of the ith process.

Through the above calculation method, it can be calculated that the balance rate of this batch of wooden furniture production line is 37.53%, the balance loss rate is 62.47%, and the production smoothing index is 32.59. According to the production balance assessment criteria in Table 3, it is found that the production line's production line balance rate is poor, which proves that there are many inappropriate processes or time-wasting problems in the production process. The smoothing index also reflects the existence of large fluctuations in the processing time of each process and the existence of bottleneck processes.

Table 3 Criteria for assessing production balance

Production line balance rate	effect
⩾90%	**excellent**
⩾80%, <90%	**very much**
⩽80%	**differ from**

4. Flexsim-based production line analysis

4.1. Analysis of existing production lines

In this study, Flexsim simulation software is used to build a simulation model of the production line to simulate the situation of producing this batch of products at that time, so as to analyze the potential problems. By importing the data in Table 2 into Flexsim, a wooden furniture production process can be built, as shown in Fig. 1. The production line of Company A works for 8 hours a day, so the simulation time is set to 480 min, in which the generator, processor, and staging area are connected by A-connection, which is used for entity-to-entity connection. It can be seen that after the production line has been running for one day, i.e., 480 min, no backlogs have been generated in any of the staging areas, while the absorber has completed a total of seven products, and there are still three products in the processing state.

Figure.1 Simulation of the original production line production flow

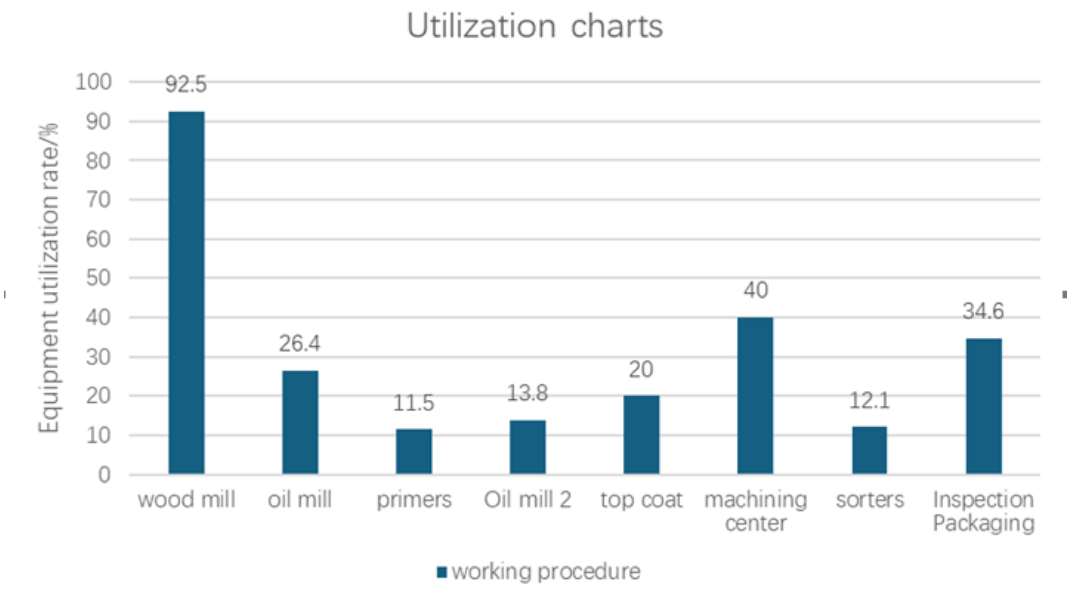

Figure 2 Initial simulation utilization graph

Through the simulation can be obtained by the utilization rate of each process equipment as shown in Figure 2, you can see that the "wood mill" the highest utilization rate of this process, that is, the "wood mill" the process of the longest working time, indicating that in the wood furniture panel production process, this process equipment The pressure is the largest, while the other processes are relatively short, that is, the other processes on the operation of the time waste, and can be seen due to the first process time is too long, seriously limiting the subsequent processes, so the first process is the bottleneck of the entire production line. The first optimization is mainly focused on the bottleneck process.

4.2. First optimization and simulation of production line

First of all, due to economic problems, we do not optimize the process from the quality of the equipment itself, but try to optimize the layout of the workshop, as well as the working habits of the staff and the order of the work, combined with the actual research on the company found that there are a number of problems with the actual production of the production line in the production of the process of "wood grinding". First of all, there is only one sanding worker in this process, and in the sanding process, it is the sanding master who chooses how to use the machine to sand the raw wood more comfortably, which leads to the poor controllability of this process, and the equipment is relatively not advanced enough, and it can't fix the wood scientifically and deal with the wood, which leads to the overall time to become longer. There are many solutions to solve the problem of this process, such as improving the equipment, increasing the production line, replacing the equipment with more advanced equipment, adjusting the position of the device, etc.. Considering the company's costs and achieving better efficiency, the most cost-effective way is to add a station, because during the actual investigation, it was found that the equipment is not always running, but a sanding worker constantly changes his position to repeatedly operate the sanding object, therefore, adding a station and providing reasonable training to the two workers can be able to do the sanding of two pieces of raw wood at the same time. The simulation is based on the Flexsim simulation software. Based on the Flexsim simulation software, we set the production time of the "wood grinding" process to 23.7 min, and the model results are shown in Figure 3. After the improvement, the production balance rate is 56.25%, and the smoothing index is 13.88. The production efficiency has been improved obviously.

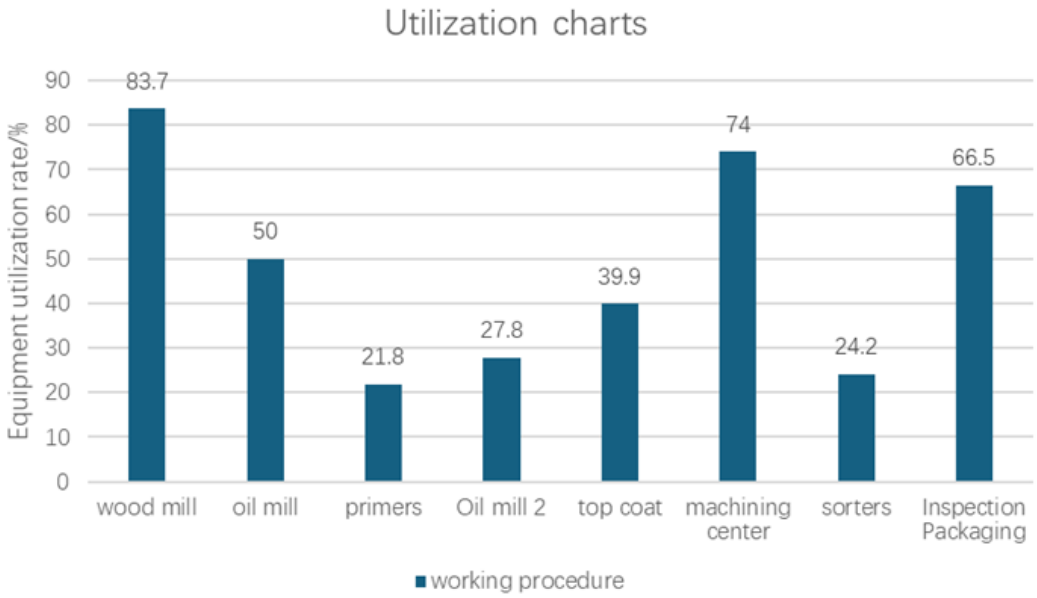

Figure 3 First Improvement Equipment Utilization Chart

4.3. Second optimization and simulation of production line

After the first optimization, we can see that the utilization rate of other processes except "wood grinding" has increased significantly, but there are still many imbalances, and we need to analyze the other processes in the workshop without changing the overall quality of the workshop equipment as much as possible. First of all, we found that the efficiency of oil grinding, priming and sorting is still not very satisfactory. In this optimization, we introduced industrial engineering methods to optimize and improve the production line.

In the oil grinding process, found that there are a lot of tools placed haphazardly on the shelves, because the operator needs to carry out two oil grinding operations, invariably on the placement of tools is more arbitrary, the first oil grinding and the second oil grinding is responsible for a total of two workers, and these two workers are usually placed arbitrarily after the tools waiting for the wood, and in the process of carrying wood there are many inconveniences, in both processes Time is wasted in both processes. To solve these problems, the layout can be planned more rationally and the productivity can be improved by setting up more work stations and separating the two oil milling processes, but at the same time of separating the processes, the work stations and equipment positions of the two oil mills can be made more lonely, reducing the time for workers to move around and look for the equipment, and decreasing the overall working time and intensity of the work.

In the process of priming, the work intensity of the workers is not high, and there is free time from time to time,. The primer operation, except for the handling part, only needs one painter to complete independently, so there is a great waste of personnel in the whole painting operation. The original production line can be seen in two primer employees, it is recommended to reduce the number of primer workers at the same time, let other auxiliary workers to assist the primer workers and topcoaters to carry out the work, so as to reduce the waste of personnel, and at the same time will not make the handling time increase, so it will improve the production efficiency.

In the machining center of this process, mainly handling wasted a considerable part of the time, and now this work will be handed over to the primer workers to assist in the completion of this part of the processing at the same time, this part of the processing is mainly dependent on the equipment, the processing of the process time is relatively fixed, but the personnel can be optimized for the distance of the movement, and at the same time the handling of the process is relatively cumbersome, before and after the handling of the work can be done by the primer and sorting workers to assist in the completion of the work, you can effectively The overall time of this process can be effectively reduced.

In the sorting process, the layout of the entire production line equipment to adjust the sorting of two workers, the dominant hand for the right hand, manufacturing, production line equipment should be placed in the order of counterclockwise rotation, easy to operate, processing, handling. At the same time, these two workers should also be responsible for the handling of finished products, so as to share the inspection and packaging process in the operation of the pressure of the workers, the use of the ECRS law to improve the entire process, so that the entire process is smoother, and in the efficiency of the same time, you can optimize the workers from two to one, to reduce waste.

In the inspection and packaging process, this step is mainly to load the processed planks with the corresponding hardware of the cabinet, but due to the fact that the whole area of the factory is small, the area left for packaging is also small, resulting in the hardware scattered all over the place, and the sorting racks of the hardware are not well utilized, and the packaging workers need to look for the tools and hardware frequently, which makes the packaging process slow. At the same time, the processed wood lumber also needs to be packed independently before being uniformly packed, and the bags can also be placed in a more reasonable location to shorten the packing time.

Therefore, in the second optimization and improvement, the working time of the oil mill and the oil mill 2 is adjusted to 10.1 min and 9.2 min, respectively, the time of the primer is reduced to 6.1 min, the production time of the primer is adjusted to 12.1 min, and the time of the machining center is

reduced to 22.2 min. The time of the sorting and the inspection and packaging is adjusted to 12.3 min and 18.7 min.

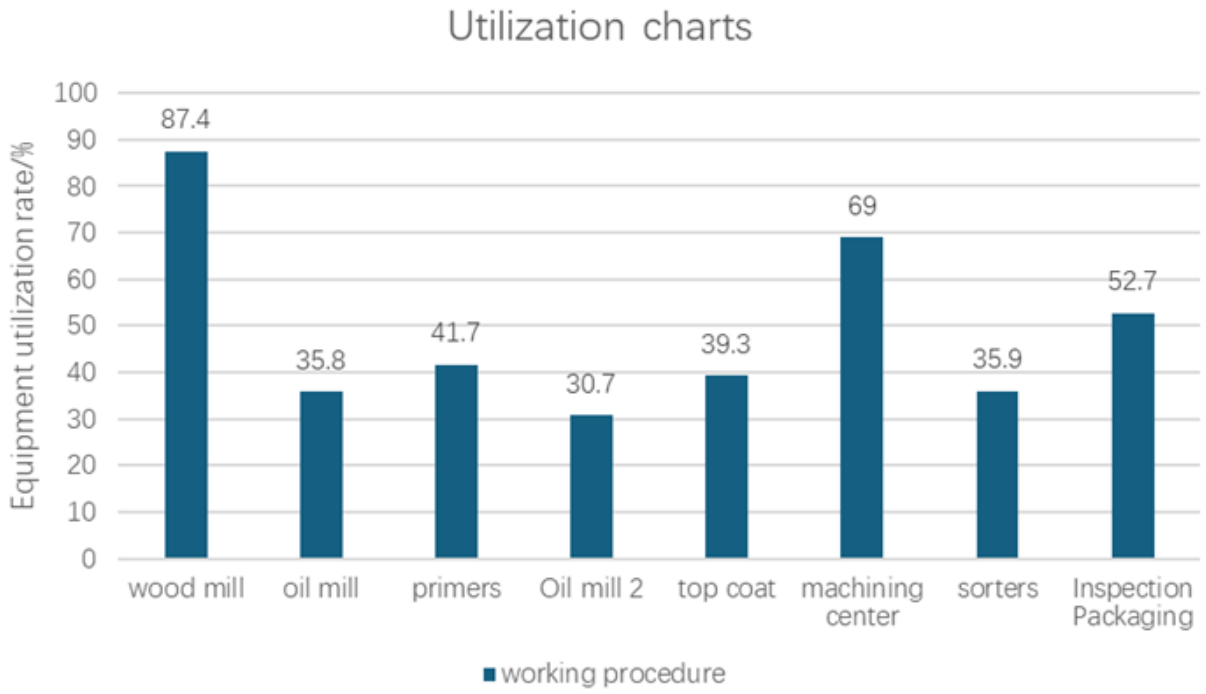

Figure 4 Second Optimization Utilization Icon

Through the above optimization, the final simulation results in Flexsim are shown in Fig. 4, and we can see that the equilibrium productivity has increased to 84.24% with a smoothing index of 6.19. The productivity has increased significantly. We can also see that from the point of view of utilization, the utilization of each process is also much higher compared with the initial, and the time wasted has become less.

At the same time, this optimization takes into account the cost of small and medium-sized enterprises, does not change the quality of machinery, and does not improve the overall number of workers, but only adjusts part of the overall process of the sequence of work and the staffing, to improve the overall quality of the movement of workers. The Flexsim simulation shows that the daily output of the wooden furniture production line is increased from 7 to 13. The results show that such optimization of the production process is effective, improving the production efficiency and making the production more orderly.

5. Conclusion

This paper is based on the data of production line of company A, and uses Flexsim simulation software to simulate its production line, to find the bottleneck process and some problems in the production process, and then combines the actual situation and industrial engineering methods to re-layout and optimize the details of the production process, such as rational allocation of personnel work, adjusting the area, and adjusting the position of the instrument placement. The data collection function in Flexsim is also used to compare the data before and after the optimization of the production line, which fully demonstrates the benefits brought by the optimized production line. The effect of production line optimization and balancing is mainly reflected in the production line balancing rate, which has increased from 37.53% to 84.24%, and the number of products produced per day has also increased from 7 to 13, which improves the production of the production line, and also provides reference for other enterprises of the same type of production.

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