Improvement of a Furniture Production Line Based on Flexsim

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Abstract

Aiming at the balance and bottleneck process of a furniture production line, this study simulates the production status by Flexsim modeling and simulation, improves the bottleneck process by using ECRS principle and program analysis, establishes 0-1 integer programming model for station reorganization, and obtains the optimized workshop processing flow by using LINGO software. The results show that the total time of the production line is reduced by 87 seconds, and the production balance rate is increased by 34.7%, which solves the practical problems in production and provides a reference scheme for production improvement.

Keywords

Flexsim modeling and simulation, 0-1 integer programming model, Lingo software, Production balance rate

1. Status analysis of workshop production line

Under the background of increasingly fierce competition and the pursuit of low cost and high interest rate, how to improve its competitiveness and become a leading enterprise in furniture industry is an urgent problem for company A. The factory is a typical traditional manufacturing enterprise, and its product type is small batch and multi variety. At the same time, there are problems such as dark production environment, old processing equipment, frequent round-trip flow between working procedures, and unreasonable product process route. The above problems lead to large reduction of production capacity, low utilization rate of personnel and equipment, and serious impact on production efficiency [1]. The factory mainly produces office appliances such as desks, filing cabinets and other products. In the process of optimization and improvement, this paper selects the representative type B products as the research object, and makes the general process flow chart, as shown in Figure 1.

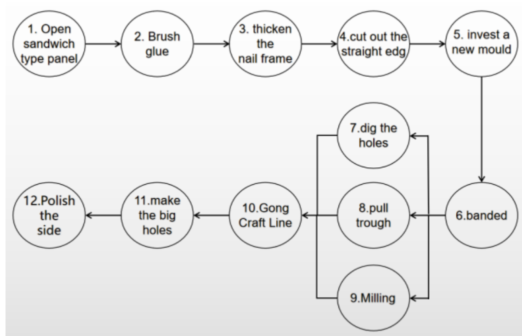

Fig. 1. B Process flow chart

The production line of No.1 furniture workshop of company a is machine group production. The parts are transported by transport vehicle. There are six processes: cutting, thickening and cold pressing, fine cutting, edge sealing, row drilling, Gong milling and grinding. It shows the position and working procedure time of furniture production line of company A in Table 1.

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Table 1. Process information table

Sequence number	Process	Processing equipment or process	Station number	Station	Station standard time/s	Number of people	Process production time/s	Total time/s
1	Board cutting	Sliding table saw	1	Open sandwich type panel	91	1	91	1728.3
2	Thickened cold pressed	Hand brush	2	Brush glue	154.5	1	541	
		Laminating	3	Thicken the nail frame	386.5	1		
3	Tailoring	ALTENDORF	4	Cut out the straight edg	79.3	1	259.3	
			5	Invest a new mould	180	1		
4	Banded	Edge Banding Machine	6	Banded	165	2	165	
5	Row drill	small CNC machining center	7	Dig the holes	92	1	247	
			8	Pull trough	87	1		
			9	Milling	68	1		
6	Gong milling	Hand gongs	10	Gong Craft Line	48	1	425	
			11	Make the big holes	168	1		
			12	Polish the side	209	1		

This paper mainly studies the process flow from cutting to trial assembly in the production line of solid wood engineering. According to the production process of type B products, after field investigation, the location layout of No. 1 workshop of the plant is made[2], as shown in Fig. 2.

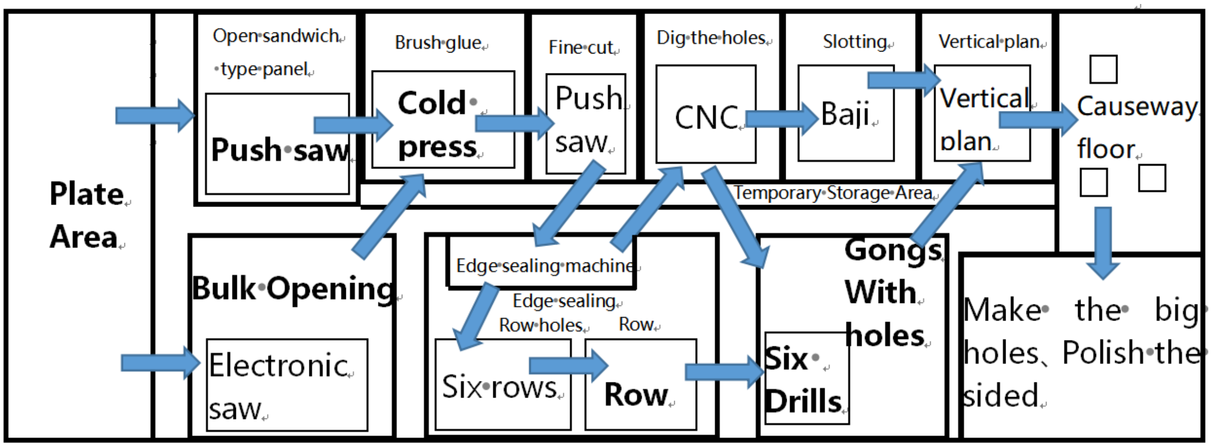

Fig. 2. Layout plan of workshop

Through the current layout, the following problems can be found:

1. In the layout of the whole production line, the storage area of wood panels has not been reasonably designed and planned (only simple drawing out the area), which leads to confusion in the placement of wood panels in the production process, which increases the searching time of operators and causes unnecessary waste of time.

2. The production line lacks unified and standard on-site management. Basically, the production is allocated by the operators themselves, and the operation action and material placement are in accordance with personal habits. In production, many operation actions do not conform to the principle of action economy, which is easy to cause problems such as increasing work load and low production efficiency [3].

3. There is an unbalanced process allocation problem in the production line, which is easy to lead to unbalanced operation time distribution, resulting in some operators working at high load and some operators in idle state[4].

2. Analysis of production line process problems

2.1 Building Flexsim simulation model

Based on the production process of No.1 Workshop of furniture factory of company a, the simulation model is established corresponding to 12 stations in the production line of type B products. Then, the production time of each station is input into Flexsim simulation model to obtain the current situation simulation diagram[5], as shown in Fig.3.

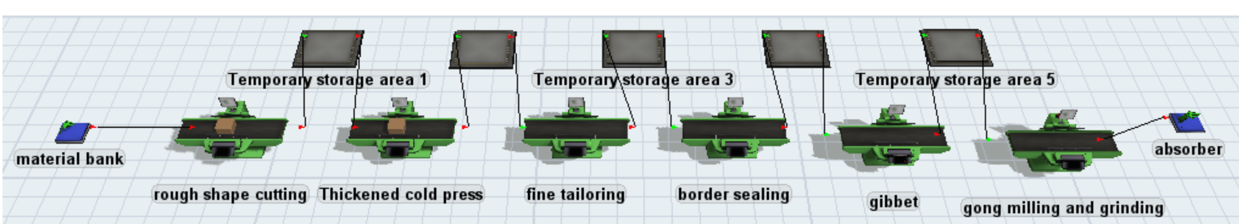

Fig. 3. Current situation simulation

According to the standard working time of 8 hours a day, the processing rate of cutting process is 16.7%, while the idle rate of thickening and cold pressing process is only 2.2%. It can be found that the bottleneck process is thickening and cold pressing. The simulation data analysis table is output from the above simulation model, as shown in Table 2.

Table 2. Simulation data analysis table

Process serial number	Process	Serial number	Work station	Processing rate	Idle rate
1	Opening materials	1	Open sandwich type panel	7%	83.3%
2	Thickened Cold Pressure	2	Brush glue	97.8%	2.2%
		3	Thicken the nail frame		
3	Fine cut	4	Cut out the straight edg	46%	54%
		5	Invest a new mould		
4	Edge sealing	6	Banded	29.2%	70.8%
5	Row	7	Dig the holes	43.4%	56.6%
		8	Pull trough		
		9	Milling		
6	Gong milling machine	10	Gong Craft Line	73.8%	26.2%
		11	Make the big holes		
		12	Polish the side		

2.1 Analysis of balance rate of production line

For the analysis and research of production line balance, it is commonly used to evaluate and compare the production line balance rate and production line balance loss rate [6]. The formula (1) for calculating the balance rate P of the production line is as follows.

$$P=\frac{\sum_{i=1}^{N}T_i}{C.T_{max}\times N}\times 100\% \tag{1}$$

Among them: $\sum_{i=1}^{N} T_i$ is the total time of all workstations calculated according to the data collected above; $C.T_{\max}$ is the maximum operation time of all processes; N is the sum of production line workstations, then, $P = \frac{1728.3}{6 \times 541} \times 100\% = 53.2\%$.

The balance rate of the production line calculated above is 53.2%, which is far lower than 86% of the production target balance rate. The reason for the imbalance of the production line is that the production rate of each process is unbalanced, and the imbalance of production capacity among the processes will lead to the accumulation of work in process and other problems, resulting in the waste of waiting.

3. Improvement plan

3.1 Methods and steps

In the first step, based on the relevant theoretical basis of ECRS, the bottleneck station in the current bottleneck process is improved combined with action analysis, and the balance rate of the production line is compared with the target balance rate [7]; the second step is to rearrange the stations by using the 0-1 integer programming modeling analysis method of operational research, and the balance rate of the production line is compared with the target again; the third step is to achieve the goal According to the process determined by lingo software, Flexsim simulation modeling evaluation is carried out according to the process determined by lingo software, and the production line layout is optimized. If it is not up to the standard, cycle steps 1 and 2. [8]

3.2 Optimization and improvement based on ECRS principle

It can be seen from the above table 2 that the bottleneck process is thickening and cold pressing, of which the longest time is nail frame thickening. Combining with the standard action analysis, the ECRS principle is used to improve the station [9], and the flow program analysis chart before and after the improvement is made, as shown in tables 3 and 4. Through the rearrangement, cancellation and combination of the actions, the handling times of the nail frame thickening station were reduced by two times, and the total time was shortened from 386.5s to 308.5s. The data analysis table after the first bottleneck improvement was made, as shown in table 5.After the first improvement, the total time decreased from 1728s to 1650.3s, shortened by 77.7s, and the production balance rate increased from 53.2% to 59.41%, increasing by 6.21%.

Table 3. Program analysis chart of nail frame thickening process (before improvement)

Department:		Number:	Statistics			
Work name: Thicken the nail frame		Number:	Project	Frequency	Time/s	Distance/m
Begin:			Fab ○	12	256	
finishing:			Inspect □	1	20	
Researcher:		Data:	Move →	7	110.5	7.5
Reviewer:		Data:	Wait D	0		
			Store ▽	1		

Work Description	Distance/m	Time/s	Process series					Remarks
			Fab	Inspect	Move	Wait	Store	
Transport floor	1.5	20	○	□	→	D	▽	
Place the bottom plate on the console		5	●	□	→	D	▽	
Topping with gum		25	●	□	→	D	▽	
Handling outer frames and joints	1.5	14.5	○	□	→	D	▽	
Place the outer frame and joints on the console		5	●	□	→	D	▽	
Splicing frame and joint		30.5	●	□	→	D	▽	
Place the outer frame joint on the rubberized		5	●	□	→	D	▽	
Mobile nail gun	0.5	12	○	□	→	D	▽	
Fixed top rack		36	●	□	→	D	▽	
Glue		25	●	□	→	D	▽	
Handling sandwich panels	1.5	20	○	□	→	D	▽	
Place the sandwich panel		5	●	□	→	D	▽	
Mobile nail gun	0.5	12	○	□	→	D	▽	
Fixed top rack		36	●	□	→	D	▽	
Glue		25	●	□	→	D	▽	
Handling roof	1.5	20	○	□	→	D	▽	
Cover the top plate to the operating table		22.5	●	□	→	D	▽	
Mobile nail gun	0.5	12	○	□	→	D	▽	
Fixed top rack		36	●	□	→	D	▽	
examination		20	○	■	→	D	▽	
Temporary storage			○	□	→	D	▼	
Total	7.5	386.5	12	1	7	0	1	

Table 4. Program analysis chart of nail frame thickening process (after improvement)

Department:		Number:	Statistics			
Work name: Thicken the nail frame		Number:	Project	Frequency	Time/s	Distance/m
Begin:			Fab ○	9	228.5	
finishing:			Inspect □	1	20	
Researcher:		Data:	Move →	5	60	3.9
Reviewer:		Data:	Wait D	0		
			Store ▽	1		

Work Description	Distance/m	Time/s	Process series					Remarks
			Fab	Inspect	Move	Wait	Store	
Handle bottom plate, outer frame and joint	1.5	20	○	□	→	D	▽	
Place the bottom plate, outer frame and joints on the console		5	●	□	→	D	▽	
Apply glue to the bottom plate		25	●	□	→	D	▽	
Splicing outer frame and joints are placed on the glue		35.5	●	□	→	D	▽	
Mobile nail gun	0.5	12	○	□	→	D	▽	
Fixed top rack		36	●	□	→	D	▽	
Glue		25	●	□	→	D	▽	
Handling sandwich panels and top panels	1.5	20	○	□	→	D	▽	
Place the sandwich panel and top panel on the operating table		5	●	□	→	D	▽	
Move the sandwich panel to the specified position	0.2	4	○	□	→	D	▽	
Fixed top rack		36	●	□	→	D	▽	
Glue		25	●	□	→	D	▽	
Move the top plate to the specified position	0.2	4	○	□	→	D	▽	
Fixed top rack		36	●	□	→	D	▽	
examination		20	○	■	→	D	▽	
Temporary storage			○	□	→	D	▼	
Total	3.9	308.5	9	1	5	0	1	

Table 5. Data analysis table after first improvement

First bottleneck improvement						
Process	1	2	3	4	5	6
Work station number - Work station production time	1--91	2—154.5	4—79.3	6--165	7--92	10--48
		3—308.5	5--180		8--87	11--168
					9--68	12--209
Process time	91	463	259.3	165	247	425
Total time	1650.3					
Balance rate	59.41%					

3.3 Optimization and improvement based on 0-1 integer programming

Because the production balance rate did not reach the ideal effect, the second improvement was carried out. In the first step, the mathematical model of the second kind of production line balance problem is established by using the idea of 0-1 integer programming, and the second step is to solve it by using Lingo software [10]. In the first step, according to the current situation of plant a, the variables and symbols used in the model are defined, and the constraint conditions are set. Finally, the 0-1 integer programming model for the balance problem of the second kind of solid wood production line is established as follows [11].

$$Minz{=}CT\begin{cases}\sum_{k=1}^{K} X_{ik}=1\,;(i=1,2,3,4\ldots,m)\\ \sum_{k=1}^{K} k(X_{jk}-X_{ik})\geq 0\,;((i,j)\in Pred)\\ \sum_{i=1}^{m} X_{ik}\,T_i\leq CT;(k=1,2,3,4\ldots,K)\end{cases} \tag{2}$$

In the second step, Lingo software is used to solve the problem and get the solution status and solution report, as shown in Fig. 4 and 5.

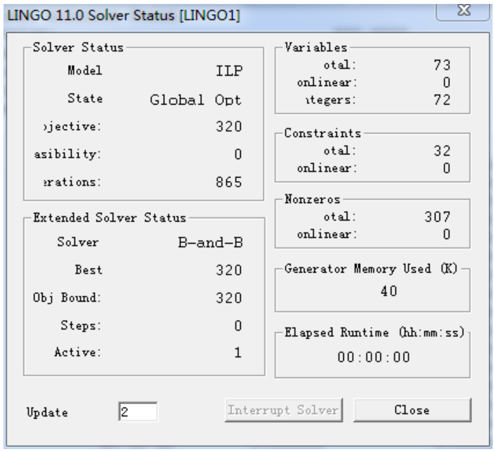

Fig. 4. Solving state

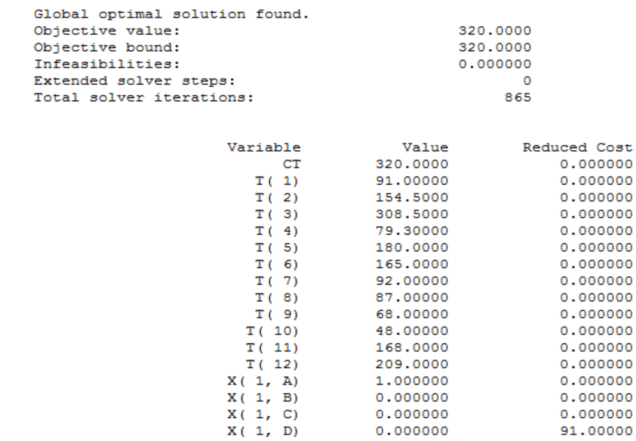

Fig. 5. Solving report

The results are shown in Table 6. When the process number M = 6, the minimum production cycle CT of solid wood production line is 320s, and the production balance rate is increased to 86%.

Table 6. Improved 0-1 integer programming data analysis table

Improved 0-1 integer programming						
Process	1	2	3	4	5	6
Work station number - Work station production time	1--91	3—308.5	4—79.3	6—165	7--92	12-209
	2—154.5		5—180	8—87	10-48	
				9—68	11-168	
Process time	245.5	308.5	259.3	320	308	209
Total time	1650.3					
Balance rate	86%					

3.4 Analysis of Flexsim modeling after improvement

In order to verify the improvement effect of the production line, it is necessary to establish a new simulation model and output new simulation data [12], as shown in figure 6 and table 7. As can be seen from table 7, the processing rate of each process has been greatly improved compared with the original situation, the idle rate has been effectively reduced, and the production processing rate of each process is more balanced.

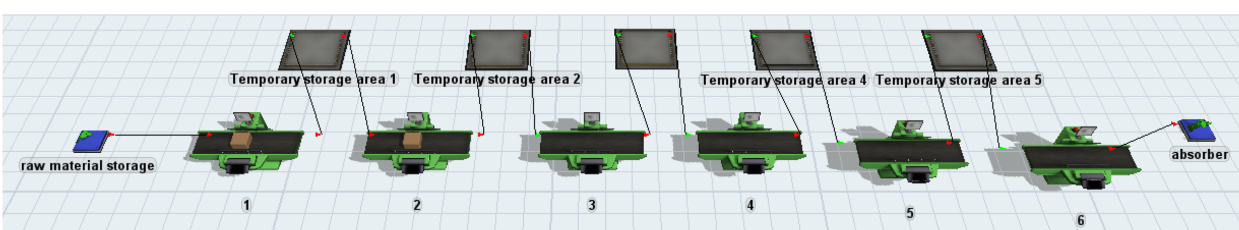

Fig. 6. Analysis of the improved simulation model

Table 7. Simulation data analysis table

Process serial number	Process production time/ s	Total time/ s	Processing rate	Idle rate
1	245.5		78.20%	21.80%
2	308.5		97.20%	2.80%
3	259.3	1641.3	81%	19%
4	320		96%	4%
5	308		94.10%	5.90%
6	209		63.10%	36.90%

3.5 Layout optimization after improvement

According to the 0-1 integer programming model and the process sequencing calculated by lingo software, the optimal production rhythm and balance rate are obtained, and the layout of No. 1 workshop of solid wood plant a is re planned, as shown in Fig. 7.

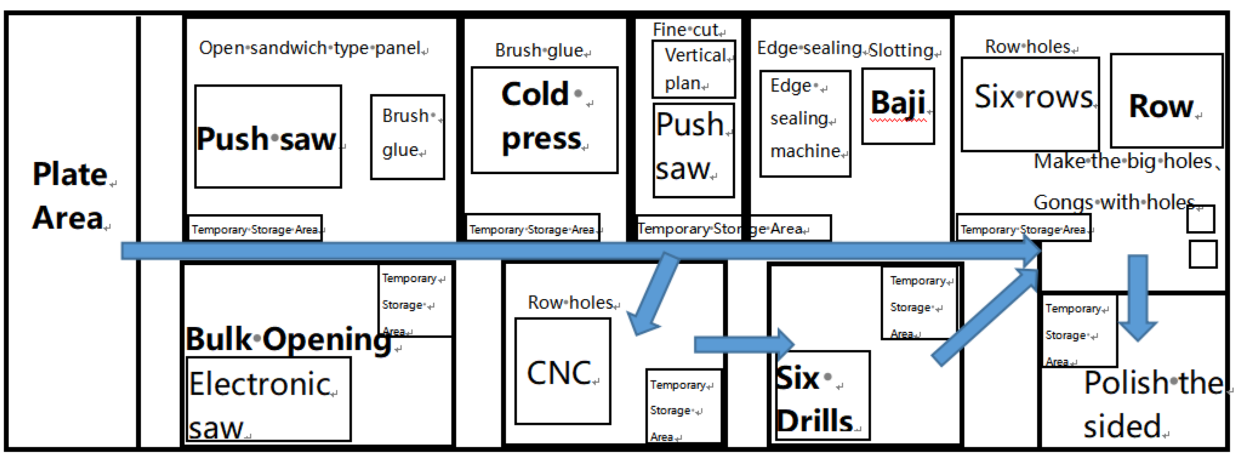

Fig. 7. Improvement of Workshop 1 of the A Factory

After the re layout of workshop No. 1, the products produced in large quantities and the products of many varieties and small batches flow through the stations involving equipment and manual operation, which are arranged in two lines, reducing the backflow of work in process during production and making the layout more reasonable [13].

4. Conclusion

The results of this paper show that traditional IE combined with operations research and lingo can solve the furniture production problem of cluster type very well [14]. The traditional IE method is used to solve the bottleneck process problem, which reduces the total production line time of workshop 1 by 78S. Operations research combined with lingo solves the production line balance problem, making the production line balance rate reach more than 86% [15], which provides a theoretical reference for solving furniture production problems.

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Biographies

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Liang Yuyan is 21 years old, borned in guangdong province, majored in Industrial Engineering, Grade 18, Zhuhai College, Beijing Institute of Technology. In this paper writing, she was mainly responsible for the work of copy writing. She has won several prizes in school competitions and thinks she has room for continuous improvement. Hoping this conference will be held smoothly.

Zhang Kaibin. from Zhuhai Institute of Beijing Institute of Technology. In this project he made together with his friends in his last college years. He was mainly responsible for collecting data, sorting out data, writing papers and arranging the work of each group. It is a great honor that this project was selected by the organizer. Hoping the conference will be a complete success.

Jiang Junhao is 24 years old, borned in Zhaoqing.He graduated from Beijing Institute of Technology,Zhuhai. His major is IE(Industry engineering). Now, he worked in a medium and small-sized enterprises(export oven). He used industrial engineering knowledge to solve production problems, and participated in many projects,including the establishment of material distribution and delivery system,the Layout optimization and site improvement.It gave me a great sense of accomplishment.

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Mo Yuwei is 23 years old, borned in guangdong province ,studying in Beijing University of Technology of Zhuhai. My major is industry engineering. She spends most of her time on study, passed CET 4 . and had acquired basic knowledge of her major during her school time.In school, she won the honorary title of excellent student and excellent League member, also won the third prize of excellent student scholarship in 2018 and the second prize of excellent student scholarship in 2020.

Zhang Yongyang is employed as an Assistant Professor and Director of Industrial Engineering by Beijing Institute of Technology, Zhuhai. He earned a Master degree of Industrial Engineering from Chongqing University. He has been recognized as a professional management with over 10 years of experience in the automotive industry. His research interests include intelligent manufacturing, flexible production, facility planning, resource optimization and lean production.

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