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Optimization and Enhancement of Company A's C Product Production Line

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Abstract: This study focuses on addressing bottleneck stations within manufacturing enterprises, emphasizing the importance of effective methods to enhance production line balance. The primary objectives are to elevate the production line's balance rate, subsequently improving production efficiency, and reducing overall production costs. The research centers around A Company's C-type liquid crystal display screen production line, employing production line balance theory and industrial engineering (IE) technology methods. Additionally, a 0-1 integer programming model is integrated to optimize and rectify production line imbalances. The optimization process results in a substantial enhancement of the balance rate and output, aligning with the evolving production development requirements of enterprises. This paper provides valuable insights into the practical application of industrial engineering techniques for optimizing manufacturing processes.

Keywords: Liquid crystal display screen; Production line balance; Industrial engineering; 0-1 integer programming.

1. Introduction

After years of development, China has become a global manufacturing power, but most of the manufacturing enterprises are in an extensive stage, most of the enterprises lack core competitiveness, the pursuit of quantity and ignore quality. The changing market environment has put forward higher requirements for Chinese enterprises, and the transformation and upgrading of enterprises has become a top priority. At the same time, the "14th Five-Year Plan" put forward higher requirements for China's manufacturing industry, enterprises from the traditional industry 2.0, industry 3.0 transformation to industry 4.0, must improve production efficiency, reduce input to improve output, reduce production costs. In manufacturing enterprises, the assembly line production mode, which aims at pursuing a "one stream" production mode, is still the core production mode of many enterprises today [1]. Therefore, the optimization of assembly line production is particularly important, and production line balance has always been the focus of assembly line optimization research, which has received the attention of various enterprises. In this paper, we take Company A's laptop LCD C production line as the research object of the problem, find out its specific problems, and analyze the reasons, based on the theory of production line balance and IE technology method, combined with the 0-1 integer planning mathematical model to put forward a set of specific improvement programs, to optimize the existing production process, improve the balance of the production line, meet the requirements of the order output, and improve the enterprise's benefits.

2. Company A Product Line Status and Problem Analysis

Founded in 1983, Company A has industrial distribution bases in many regions at home and abroad. It is a listed company mainly engaged in computer, communication and other electronic equipment manufacturing. After more than 30 years of development, the company has a total number of employees more than 25,000 people, the annual revenue of more than 30 billion yuan. Liquid crystal display is the first batch of products produced by Company A, and it is also the product with the largest demand and production at present. This paper chooses the liquid crystal display of laptop computer as the research object. Due to the impact of the novel coronavirus pandemic, consumer demand for computers is increasing, and the market demand for Company A's products has also increased significantly. In order to seize more market share, Company A has built a number of new product lines. However, because most of the production lines are simply copied in accordance with the existing production lines, the production process and equipment have not been updated in time, and there are many unreasonable production line layout. With the substantial increase in order volume, the existing production capacity can not meet the market demand, and the phenomenon of product shortage often appears, and it is urgent to optimize and improve the product line.

At present, Company A adopts an 8-hour working day and needs to complete the output of 240 products per day to ensure the completion of the daily order requirements. the main process of the products of production line C can be divided into 10 processes, which contain a total of 31 operational elements, the specific content is shown in Table 1. According to the formula related to production line balance [2], we can get the production line balance rate (P) = 79.14%; balance loss rate (d) = 20.86%; production line smoothing index (SI) = 36.88; daily output = 217 units (rounded). From the above indicators, it can be seen that the existing production line balance rate is low, there is still much room for improvement, and the daily output is far lower than the daily order demand, so improving the production line balance rate and increasing the product output is an urgent problem to be solved.

Table 1. Product process flow and standard operating time

Process	Operation	Standard time (s)
1 Glass substrate handling	1 ITO glass input	3.39
	2 Glass washing and drying	110.51
2 ITO graphic pre-etching	3 Photoresist coating	16.02
	4 Prebake	34.76
	5 Exposure	25.06
	6 Expose	33.46
	7 Indurate	22.37
3 Etching and de-molding	8 Etch	33.50
	9 De-mold	38.78
	10 Purge and dry	59.86
4 Directional alignment	11 Coating agent	20.15
	12 Solidification	68.96
	13 Directional friction	22.79
5 Empty box production	14 Upper glass plate printing adhesive	8.48
	15 Lower glass plate printed adhesive	8.49
	16 Spray liner	11.30
	17 Antagonistic press-fit	29.13
	18 Solidification	73.18
6 Liquid crystal infusion	19 Cuts	22.69
	20 Perfusion liquid crystals	51.17
	21 Seal	26.00
7 Reassign	22 Purge	66.35
	23 Reassign	12.91
8 Finished product inspection	24 Light table inspection	20.19
	25 Electrographic inspection	30.68
9 Polarizer	26 Attach the polarizer	34.90
	27 Stick down the polarizer	34.94
	28 Upper polarizer defoamer	11.31
	29 Lower polarizer defoamer	11.60
10 Packaging and storage	30 Wrap	46.34
	31 Store	56.50

3. Optimization and Comparison

3.1. 0-1 Integer Programming Modeling

In real problems, involving yes or no decision problems, there are only two possible choices yes or no, since there are only two choices, we only give two values of 0 and 1 to the decision variables, such a linear program that requires all decision variables can only take 0 or 1 is called 0-1 linear programming. Adopting the 0-1 integer planning method, the process flow and operation sequence of the C product production line is abstracted into a mathematical problem, constructing a model that satisfies the constraints, and reassembling each operation element to finally achieve the effect of a smooth production process and balance of each process. The 0-1 integer planning model is constructed with two goals: first, to reduce the number of workstations, and second, to reduce the production beat [3]. Therefore, the following two types of production line equilibrium optimization models are established: (1) Type I model, where the production beat, the number of work elements, and the standard time of work elements of the whole production line are known, and the minimum number of work processes is found, subject to all constraints. (2) Type II model, keep the total number of processes unchanged, and find the shortest production beat subject to all constraints.

3.2. Solving 0-1 Integer Programming Models

In this paper, Lingo software is used to program and solve the 0-1 integer planning model of the C product production line of Company A. The optimization results of two types of models are shown in Table 2. From the optimization results of the first class, when the product production line beat CT = 132.14s, the minimum number of workstations N = 9, and the number of workstations decreased by 1 compared with the original process. Calculated to obtain the production line balance rate of each evaluation index: production line balance rate (P) = 87.93%; balance loss rate (d) = 12.07%; production line smoothing index (SI) = 19.68; daily output = 217 units (rounded).

Table 2 Class I 0-1 integer planning model solution results

Working procedure	Operational elements	Time (s)
Process 1	1, 2, 3	129.92
Process 2	4, 5, 6, 7	115.65
Process 3	8, 9, 10	132.14
Process 4	11, 12, 13	111.90
Process 5	14, 15, 16, 17, 18	130.58
Process 6	19, 20, 21	99.86
Process 7	22, 23, 25	109.94
Process 8	24, 26, 27, 28	101.34
Process 9	29, 30, 31	114.44

From the results of Type II optimization, when the number of production line stations is determined to be unchanged N = 10, the minimum station beat is CT = 113.90s, compared with the original bottleneck process time reduced by 18.24s. Calculated production line balance rate of the evaluation indexes as follows: production line balance rate (P) = 91.81%; balance of the loss rate (d) = 8.19%; production line smooth index (SI) = 13.80; daily output = 252 units (rounded).

Table 3. Class II 0-1 integer planning model solution results

Working procedure	Operational elements	Time (s)
Process 1	1, 2	113.90
Process 2	3, 4, 5, 6	109.30
Process 3	7, 8, 9	94.65
Process 4	10, 11	80.01
Process 5	12, 13, 14, 15	108.72
Process 6	16, 17, 18	113.61
Process 7	19, 20, 21	99.86
Process 8	22, 23, 25	109.94
Process 9	24, 26, 27, 28, 29	112.94
Process 10	30, 31	102.84

3.3. Comparison and Selection of Optimization Options

From the above, it can be seen that after the optimization of the two types of 0-1 integer models, the relevant production indexes of the C product production line have been substantially improved compared with the original scheme. However, specifically, the evaluation indexes of the optimization results of the Type II 0-1 integer planning model are significantly better than those of the Type I 0-1 integer planning model. Especially in terms of daily output, the daily order quantity of Company A's C product is 240 units, and the Type I optimization scheme does not improve the product output, and the daily output is still 217 units < 240 units, which cannot meet the daily order demand. While the Type II optimization plan, the product output is improved significantly, the daily output is 252 sets > 240 sets, which can effectively solve the current urgent needs of Company A. Therefore, after comprehensive consideration, it is recommended that Company A selects the Type II 0-1 integer planning improvement plan as the final optimization plan, which recombines the operational elements between processes to improve the output and production efficiency.

4. Conclusion

This paper chooses Company A's liquid crystal display product line C as the research object to explore the methods and specific programs to improve its production line balance and product yield. After describing the production process and determining the standard operation time, two types of 0-1 integer planning models are constructed, and Lingo software is used to find out the optimal allocation of operation elements, and the two optimization schemes are compared and analyzed, and it is found that the Type II 0-1 integer planning improvement scheme is more competitive, and it is chosen as the final solution. After optimization, the number of workstations remains unchanged at 10, but the balance rate of the production line is further increased to 91.81%, the smoothing index is reduced to 13.80, the production beat is reduced to 113.90s, and the daily output is increased to 252 units, which is an obvious optimization effect.

In short, production line balance is of great strategic significance for the development of manufacturing enterprises. At present, many scholars have proposed numerous theories and methods for the study of production line balance. Due to the diversity of production line objects in enterprises, specific production line balance problems require specific theories and methods for research and analysis. How to put forward a universally applicable theory and method of production line balance under the premise of production line diversity is of great significance to the development of enterprises and countries.

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