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Balancing Assembly Line of Sofa Sets in a Furniture Factory and Measuring the Efficiency of the System by A Simulation

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Abstract

The assembly line is a system which is formed by the integration of some workstations by a material handling system. The purpose of the system is to achieve a finished product by the assembly of the components of it. Assembly process is composed of the order of the components of the work, or of the tasks that have to be performed in order. The assembly of the components is performed by considering the priority of them in the related workstations which are decided previously

Position Weighted Balancing Method which is one of the intuitive solution methods of the Assembly Line Balancing Problems is used in this study. By this method, the manufacturing operation time in a production line of the workflow plan in a furniture factory has been examined; and conclusions have been proposed accordingly. Within the study, time measurements, data from work study and workflow plans during the production process have been modeled with the help of Arena simulation software. The weak points of the system have been detected according to simulation data of the current state. Considering these weak points, Position Weighted Balancing Method has assigned operations to the workstations. According to the results of the simulation, improvements have been observed on the parameters of product quantity and the system performance (the duration of supply, the rates of capacity utilization of personnel, cycle time and the workstations).

Key words: Assembly Line Balancing, Production Systems, Simulation, Furniture Factory

1. Introduction

The system is a set of elements that are related to each other and brought together to perform a specific purpose. Each system consists of elements, inputs, production process, outputs, feedback and environmental elements [1]. Processes of work items can be realized by organizing/structuring of separate workers' organizations with different methods. Faster and more economical production can only be achieved if the sum of the processing times of each individual workstations of the work item processes is allocated in a balanced and even distribution. Parts to be operated on an assembly line can be assembled by taking into account the constraints such as priority relationships and cycle times. Because of this, the system consisting of the array of workstations is called as the assembly line [2]. Assembly line balancing is a method applied to increase production speed and to provide an economic solution. Nowadays it is observed to become imperative to implement different methods in order to be able to provide adequate flexibility in terms of production quantities, price pressures, efficient design of production lines and various fluctuations in these lines.

In the assembly lines; various raw materials, semi-finished products, and parts are systematically combined to produce a complex product. Cars, tractors, refrigerators, and televisions are some of

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the products manufactured on an assembly line. Assembly lines allow the same or similar products to be produced in high quantities and at low costs.

The main objectives of the enterprises are to raise the level of efficiency, increase capacity and quality, reduce costs and humanize the working environment. In order to achieve these goals, it is necessary to redesign the work methods that are used in the manufacturing systems, including the workforce, machinery, materials and equipment.

In this study, it is aimed to solve a single model assembly line balancing problem by considering a sofa model in a furniture factory. The position-weighted assembly line balancing method is applied because of the fact that the production is done in a labor-intensive way by taking advantage of the complicated nature of human power and the assembly line balancing problems. The operations related to the sofa model, such as priority associations and standard durations, were obtained by the work performed at the workplace. After the position weights are calculated, the work items are assigned to the stations starting from the work item with the position weights sorted in decreasing order and having the largest position weight. Then, simulations of the existing system and the improved organizational structures with the position weighted method are performed. The current model and the improved model of both systems are obtained and interpreted by mathematical calculations both manual and simulation methods.

2. Literature Review

The assembly line balancing first emerges as an idea of Bryton's work (1954) [3]. The first scientific study published was by Salveson (1955) [4]. After Salveson's work, many methods for line balancing have been developed. Dar-El (1973) [5], Dar-El and Rubinovitch (1979) [6], Baybars (1986) [7] have developed various intuitive methods while Bowman (1960) [8] used integer programming, Held et al (1963) [9] focused on dynamic programming and Jackson (1956) [10] worked on branch and boundary approaches. When meta-intuitive techniques in the literature are analyzed it is seen that, Suresh and Sahu (1994) [11] used simulated annealing, Peterson (1993) [12] used taboo search, Falkenauer and Delchambre (1992) [13], Dimopoulos and Zalzala (2000) [14], Aytug et al (2003) [15], Scholl and Becker (2006) [16] used genetic algorithm approaches to solve the assembly line balancing problem. In addition, classification of assembly line problems has been the subject of studies of Baybars (1986) [7], Becker and Scholl (2006) [16], Erel and Sarin (1998) [17], Ghosh and Gagnon (1989) [18]. The growth of problem dimensions has increased the using of intuitions.

3. Method

3.1. Balancing Assembly Line

Several constraints are considered in order to plan the assignment of operations to workstations in the balance of assembly lines. These constraints are primary constraints and secondary constraints. The occurrence of these constraints can make a complete line balancing in real life difficult and even impossible. For this reason, it is inevitable that there is some loss of balance or balancing delay in line balancing [19].

At the beginning of the primary constraints is the cycle time. The daily exact production amount target and the exact working time per day determine the cycle time. Cycle time is the maximum time value that the product can stay at any station on the assembly line, or the operator on a workstation needed to complete the work that needs to be done [20]. Priority associations are another set of primary constraints. The work items that should be completed must be taken into consideration during the assignment of work items to stations.

Secondary constraints include position constraints, fixed hardware constraints, station load, and work items to be assigned (and not to be assigned as well) to the same station. Position constraint refers to the relationship between the position of the assembled product and the position of the workers on the band. Fixed hardware constraints; some machines and fixed equipment are integral parts of the line and cannot change. Station load is an important consideration and it is preferred that the load of the first stations is less than 100%. Work items that are chosen to be assigned to the same station must be assigned to the same or successive stations. The purposes to be achieved in establishing an assembly line are; to provide a regular material flow, using human power and bench capacity at the highest level, to complete the operations as soon as possible, minimizing the number of workstations on the assembly line, minimizing the idle times, distributing the idle times properly between the workstations, and minimizing the production costs[19].

3.2. Position Weighted Assembly Line Balancing

Position weighted line balancing is one of the intuitive solution methods of balancing the assembly lines. This method was developed by Helgeson and Birnie [21]. In this method, for each work item, a value is assigned as "position weight" by summing the duration of its own period and the operations that cannot be started before it is finished. Steps to be followed in position weighted assembly line balancing are as follows:

- The settlement plan of the factory is established.
- The main line workflow diagram of the current model is drawn and the work items are specified.
- Time measurements of work items are made using the chronometer method and standard times are determined.
- Priority associations between work items are determined and placed in the table.
- The efficiency analysis of the current model (cycle time, the minimum number of workstations, system efficiency, average workstation time, balance loss and line activity) is calculated.

- The position weight for each work item is determined (the standard duration of the work item + the standard durations of all work items affected by the work item).
- Work items are sorted in their stations in decreasing order of position weights.
- For the proposed model, the work items are started to be assigned to the stations, taking into account the priorities according to the position weight sequences.
- The assignment is continued until the desired cycle time is reached. When the cycle time is reached, it is passed to the other station.
- Assignment continues until all work items are assigned to a station.
- For the proposed model, efficiency analysis (cycle time, the minimum number of workstations, system efficiency, average workstation time, balance loss and line activity) are calculated.
  The results of the current model and the proposed model are compared with each other [6].

3.3. Simulation Method and System Performance

Simulation; is a technique that evaluates the behavior of the system or evaluates different strategies and evaluates the properties and behavior of these systems through a computer. A theoretical or physical real system is modeled on the computer environment and then operated

4. Case Study: Balancing Assembly Line In a Furniture Factory and Simulation Study

In this study, a sofa assembly line balancing was carried out in a furniture operation located in a plant in Isparta, Turkey. The furniture factory under study has been serving in Isparta since 1985 (with 60 personnel in 2018) . Between 15 and 20 kinds of seating groups are produced in the factory each year. A simple settlement plan of the factory is given in Figure 3 and a part from the work study of a sofa/sitting group is also given in Figure 3 and Figure 4.

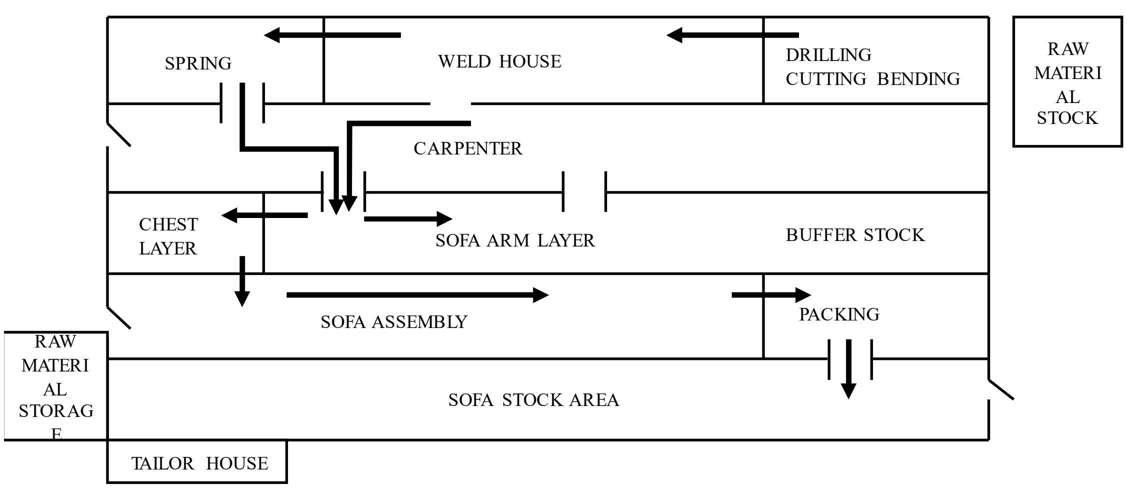

Figure 3: Furniture Factory Settlement Plan

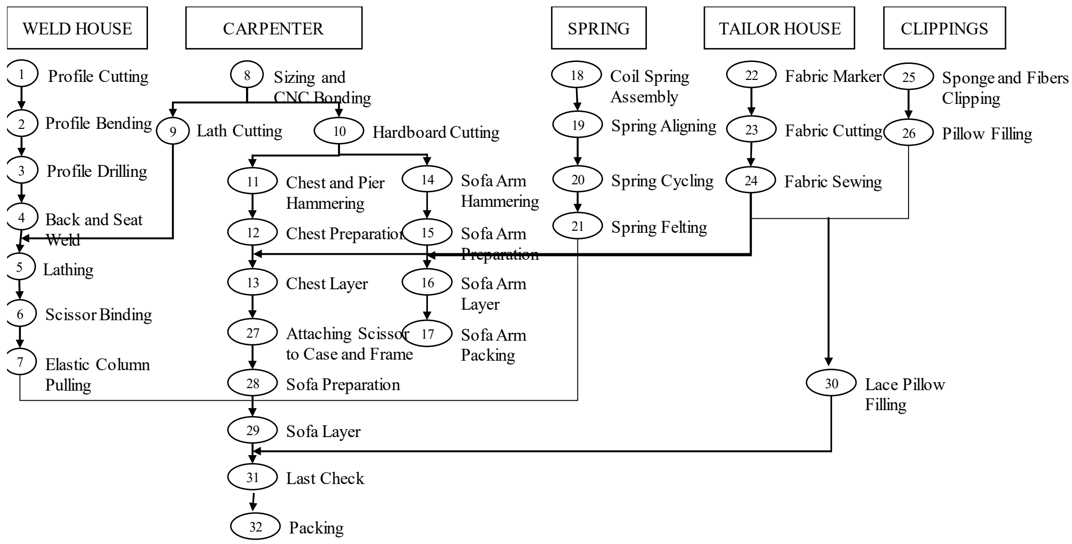

Figure 4: Sofa Production Main Line Work Flow Diagram

5. Results

Table 1 gives the results obtained with the mathematical models of the current structure. According to the results, in the proposed system, cycle time (C) decreased by 54,89 %, the number of workstations increased from 6 to 13, efficiency increased from 30,2% to 66,6% and the average workstation time (C *) decreased by 33.3%, while efficiency parameters remained unchanged.

	C (seconds)	n_{enk}	Efficiency (%)	C*(seconds)	D (%)	HE (%)
Current	900	6,012	30,2	901,89	-0,21	102,527
Proposed	406	13,33	66,6	601,3	-48,09	102,53
Change (%)	54,89	121,72	120,53	33,33		0,00292

Table 1. Line Balancing Efficiency Analysis Results

Simulation results are given in Table 2. In the proposed system, the lead time is considerably reduced. From here it can be reached that the waiting times and stocking times are decreased. While machine capacity utilization remains the same, personnel capacity utilization rates have improved considerably. The proposed structure doubles the amount of the product.

	Lead Time (second)	Machine Capacity Utilization Rate (%)	Personnel Capacity Utilization Rate(%)	Amount of Product
Current	69546	44.19	28.58	149
Proposed	2368	42.06	41.72	354

Table 2. Simulation Results of Current and Proposed Models

5. Conclusion

From the previous results presented on Table 1 and 2, it is deduced that the proposed model obtained by position-weighted line balancing provides much better results than the existing system. This conclusion is also supported by both mathematical and simulation results which are obtained from the outputs of assembly line balancing. Main reasons in this improvement are, the decrease in lead time / duration of supply and the decrease in the waiting period between raw materials and finished products as well as the period between the raw material and intermediate stocks.

Although the rate of machine capacity utilization remains the same on the simulation results, a high increase in personnel utilization rates indicates that the work items are highly balanced to the stations. From here it is possible to reach the result that the personnel are better assigned to the terminals. It is also seen that the balance losses are reduced in the proposed system.

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