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Sugabee Assembly Line Balancing Study



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# ABSTRACT

In cases where there is high demand in continuous production systems where production is carried out in units, the most basic way to ensure high production speed is to balance the assembly line. By balancing the assembly line, the work steps are grouped, and stations are created, the cycle times of each station are brought closer to each other, and thus the assembly line is operated without any interruption.

The aim of this study is to improve the quality of sugar production process in the lollipop manufacturing line in Sugabee Confectionery Co. The study was carried out using assembly line balancing method. The main problem is whether the workstations are sufficient, and total production time is more than the employees two hours overtime. For this purpose, the flow of the line was first observed and analyzed. As a result of the observation, assembly line balancing was conducted using by MATLAB. In addition, the goal is reducing the cycle time and balancing the assembly line. Based on the research, it has been shown that the system can develop effectively with assembly line balancing.

Keywords: Efficiency, Lollipop Manufacturing Process, Assembly Line Balancing, Cycle Time

# INTRODUCTION

Meeting the customer needs on time and meeting the expectations in full has made businesses need to continuously improve their production processes. Considering today's competitive conditions, besides the quality factor for the companies, the production stages of the product such as flexibility in production processes and production speed have gained importance. From the ancient times to the present, the concept of production with assembly has undergone great changes. The most important milestone in assembly was the invention of assembly lines. In 1913, Henry Ford and his team applied the first assembly line to automobile production. Many enterprises use assembly lines to improve the performance of their production processes and adjust the flow rate of the materials they will supply from other production stages and outside the facility according to the needs of the final assembly line.

At the end of 2010, AIB SUGABEE nap in a closed area of five thousand square meters, designed as per BRC Global Food Standards such as ISO 22000, property, production started with annual capacity of ten thousand tons of Hard Candy. Acting on the principle of continuous development, the factory offers 3D lollipops produced for children, tin cans for adults, candy canes, fun and surprise products, products designed in different sizes and make a difference. Traditional flavors such as cinnamon, damla gum, Turkish coffee are moving into products. The factory has three different production lines such as bonbon line, lollipop line, and soft and filled candy line. The “Ice-fresh” product we have developed in the light of R & D studies takes them one step further. Due to the ethics of healthy product development, natural paint obtained from real fruit juice and plants is used in the products. Not only in Turkey, European Union countries, USA, Central Asia and the Middle East, especially more than thirty countries, exports, Turkey's largest confectionery exports to the newest company has taken the title. The factory has three different production lines such as bonbon line, lollipop line, and soft and filled candy line.

Lollipop production processes include several steps. First, sugar producers blend water, hot sugar and glucose syrup. After cooking, colors and flavors are added with manpower. The mixture is remolded in a remolding machine to be pulped. Some lollipops have gum, in additionally there is a machine for adding gum to the lollipop. Then the remolded mixture goes to the lollipop line. Here, a mixture of gum and sugar is added to the sticks. Then, the lollipops enter the cooling tunnel. After that, the lollipops go to the packaging machine. Finally, the sugar is bagged and shipped.

## LITERATURE REVIEW

In the study of Scholl (1993), study presents benchmark data sets for Simple Assembly Line Balancing Problems (SALBP) which may be used to test and compare solution procedures. The (general) SALBP consists of assigning tasks to workstations of an assembly line such that sum of idle times is minimized. The number m of stations as well as the production rate, or equivalently, the cycle time c must be determined simultaneously. Additionally, precedence constraints between the tasks must be considered. Two restricted versions of the problem, often considered in the literature, are SALBP-1 and SALBP-2. SALBP-1 is to minimize the number of stations for given cycle time whereas SALBP-2 is to minimize the cycle time for a given number of stations.

The analysis of the brake assembly line in the enterprise is detailed in this study. The aim of the study of Ozkiran et al. (2011) is to reduce the amount of intermediate stock available and to ensure the continuity of the flow without interruption. For this purpose, the flow of the line was first observed and analyzed. As a result of the observations, human machine diagrams and time study studies were conducted. Improvement is such that it does not make any difference during the work steps. Because it is not possible to change the order of operations on this product. Changing their order prevents the next operation from being performed. Considering these constraints, balancing was made by comparing the time difference between the operators and the duration of the work steps. As a result, in the study of Ozkiran et al. (2011) an assembly line balancing problem is addressed. The results and evaluations were made with the tables and calculations related to these methods and the first values ​​and the last values ​​were verified.

The study of Scholl et al. (1997) heuristics for Type 1 and Type 2 of the Simple Assembly Line Balancing Problem (SALBP) are described. Type 1 of SALBP (SALBP-1) consists of assigning tasks to work stations such that the number of stations is minimized for a given production rate whereas Type 2 (SALBP-2) is to maximize the production rate, or equivalently, to minimize the sum of idle times for a given number of stations. In both problem types, precedence constraints between the tasks must be considered. The study of Scholl et al. (1997) describes bidirectional and dynamic extensions to heuristic priority rules widely used for SALBP-1. For the solution of SALBP-2 Scholl et al. (1997) present search methods which involve the repetitive application of procedures for SALBP-1. Furthermore, improvement procedures for SALBP-2 are developed and combined with tabu search, a recent strategy to overcome local optimality. Several optional elements of tabu search are discussed. Finally, the application of a nontraditional tabu search approach to solve SALBP-1 is investigated. Computational experiments validate the effectiveness of the new approaches.

Kumar et al. (2013) works on reviews of different works in the area of assembly line balancing and tries to find out latest developments and trends available in industries in order to minimize the total equipment cost and number of workstations. The main objective of line balancing is to distribute the task evenly over the workstation so that idle time of man of machine can be minimized. Assembly line balancing is to know how tasks are to be assigned to workstations, so that the predetermined goal is achieved. Minimization of the number of workstations and maximization of the production rate are the most common goals. Also observed that equipment costs, cycle time, the correlation between task times and equipment costs and the flexibility ratio needs a great attention. The results of the research presented four methods. Firstly, a heuristic procedure for solving larger size of problems can be designed. Secondly, paralleling of workstations and tasks may be studied to improve the line efficiency. Thirdly, to select a single equipment to perform each task from a specified equipment set. Finally, bee and ant colony algorithm to be adopted for finding number of workstations.

The traditional assembly line balancing problem considers the manufacturing process of a product where production is specified in terms of a sequence of tasks that need to be assigned to workstations. Each task takes a known number of time units to complete. Therefore, precedence constraints exist among tasks: each task can be assigned to a station only after all its predecessors have been assigned to stations. The U-shaped assembly line balancing problem is a relatively new problem derived from the traditional assembly line balancing problem. In the U-shaped assembly line balancing problem tasks can be assigned to stations either after all its predecessors or all of its successors have been assigned to stations. The study of Wainwright et al. (1998) presents a genetic algorithm (GA) solution to the Type I U-shaped assembly line balancing problem. The research of Wainwright et al. (1998) provides a global framework which can be used to deal with the two possible variations of this problem, minimizing total idle time, and balance of the workload among stations, or a combination of both. Wainwright et al. (1998) developed six different assignment algorithms as a means for interpreting a chromosome and assigning tasks to workstations. The results show the GA to be an excellent technique for this problem. In the sixty-one standard test cases from the literature, the GA obtained the same results as previous researchers in forty-nine cases, superior results in eleven cases, and in only one case did worse. Moreover, the GA proved to be computationally efficient.

When defining the layout for flow or production lines, it is necessary to perform the Line Balancing. Silva et al. (2011) was presented an application that was developed to solve Assembly Line Balancing problems using a Genetic Algorithm. There are two types of Simple Assembly Line Balancing Problems (SALBP): SALBP-1: Given the takt time, minimize the number of workstations. SALBP-2: Given the number of workstations, minimize the cycle time. To test the GA, the developed application was applied to an example problem, in order to make possible a comparison of the obtained results with those obtained using heuristic methods. Furthermore, it should be mentioned that the GA found more than one feasible solution to the problem. Given the results obtained with this application, Silva et al. (2011) intend to improve the GA in order to allow the user to dynamically adjust the cycle time or the number of workstations to improve the results for more complex problems.

Since the time of Henry Ford, several developments have been taken place in production systems which changed assembly lines from strictly paced and straight single-model lines to more flexible systems as parallel workstations, customer-oriented mixed-model and multi-model lines, U shaped lines and unplaced lines with intermediate buffers. In the study of Ghutukade et al. (2013) a problem of line balancing in cashew nut shelling machine production has been discussed using ranked position weighted method. The main purpose of the study of Ghutukade et al. (2013) is to represent use of Ranked Position Weighted Method (RPW) method to develop the assembly line and balancing that line. With the study of Ghutukade et al. (2013) it is found that RPW method is useful when the less data is available. Moreover, with the help of RPW method, one can find out the way to synchronize the workstations for the workflow and sequencing. Therefore, the bottlenecking of the assemblies can be reduced. In this case study numbers of workstations have been decided and proper layout has been proposed based on RPW method. Before implementing the RPW method production rate was twenty-six machines per month. And after implementing the RPW method, production rate was increased by thirty eight percent with thirty-six machines per month (Ghutukade, 2013; Sawant, 2013).

# DEFINITION OF PROBLEM

Assembly line balancing is a simple implementation but, it can cause major problems as it is ignored in most facilities, including large facilities. There is also a lack of assembly line balancing in Sugabee Confectionery Co. Problems requiring assembly line balancing are; first, candy makers blend water, heat sugar and glucose syrup. Once cooked, colors and flavors are added with manpower. Therefore, this injection process causes of waste of time, for this reason, lollipop product cycle time is increasing. The remolding process is making with kneader but still using manpower because kneader is not enough for remolding. For this extra process, there is a temperature loss. Some lollipops are including gum thus, there is a machine for adding a gum into the lollipop. Gum temperature is very low therefore, there should be a process for heating the gum, there is also a waste of time in this process. Then the blend goes to a lollipop batch roller and lollipop attaches to the stick. Because of candy heat, sticks are becoming useless, for this reason it causes shrinkage. Next, when the lollipops are in the cooling tunnel, the powder is used to prevent the sugars from sticking together. There is also a problem in this cooling tunnel process which is welded since the powders adhere to the fans, cooling is becoming difficult. Then lollipops go to the flow pack machine. Finally, the candy is bagged and shipped. The problems were examined and decided to reduce or increase workstations to achieve efficiency caused by excess of total time. The goal was to achieve task groupings representing approximately equal time requirements. Therefore, minimizing idle time caused high utilization of labor and equipment. The aims are to both increase productivity and reduce working hours by reducing production time at the factory. Thus, a solution including other problems will be produced towards the assembly line balancing.

# METHODOLOGY

In this part of the study, a mathematical programming model proposal with a serial task assignment is used, aiming to minimize the cycle time. As it is be in the literature, there are many approaches to assembly line balancing. To the matter in hand, in this study is Simple Assembly Line Balancing 2 (SALBP 2). The purpose of this method is, Type 2 (SALBP-2) is to maximize the production rate, or equivalently, to minimize the sum of idle times for a given number of stations. In both problem types, precedence constraints between the tasks have to be considered (Scholl,1997).

Assembly line balancing is a production strategy that sets an intended rate of production to produce a particular product within a particular time frame. Furthermore, the assembly line needs to be designed effectively and tasks needs to be distributed among workers, machines and workstations ensuring that every line segment in the production process can be met within the time frame and available production capacity. Assembly line balancing can also be defined as assigning proper number of workers or machines for each operations of an assembly line so as to meet required production rate with minimum or zero ideal time.

Benefits of Assembly Line Balancing in organizations are, improved process efficiency, increased production rate, reduced total processing time, minimum or zero ideal time and lastly potential increase in profits and decrease in costs.

|  |  |
| --- | --- |
| A (Vacuum Sugar Cooking Machine) | 3 minutes |
| B (Manuel Injection Process) | 1 minute |
| C (Kneading Machine) | 3 minutes |
| D (Decoloring, Blending the Aroma) | 2 minutes |
| E (Adding the Gum) | 1 minute |
| F (Batch Roller) | 5 minutes |
| G (Cooling Tunnel) | 4 minutes |
| H (Waiting for Cooling) | 30 minutes |
| I (Lollipop Packing Machine) | 134 minutes |

Table 1 Assembly Line Balancing



## Precedence Diagram

The diagram showing the priority relationships between the tasks will be as follows:

## Mathematical Model

The integer programming model of the problem defined in the context of these explanations is created as follows.

### Parameters

|  |  |
| --- | --- |
| : | Processing time of the work item i (i = 1, 2, ..., N)  N = number of products |
|  | The first workstation to which work item can be assigned |
|  | The last workstation to which work item can be assigned |
|  | Number of workstations expected to be required at the end of balancing |
|  | Set of work items that must have been completed before the work item |
|  | Set of work items that can be completed after the work item |
|  | Set of all work items that can be assigned to kth workstations |

Table 2 Parameters

### Objective Function

In the mathematical model, the objective function is the minimization of the sum of the cycle times of each model.

### Assignment Constraints

It ensures that each task is assigned to only one station. In other words, a task can be assigned to only one position within a station.

For task 1 (i = 1):

For task 2 (i = 2):

For task 3 (i = 3):

For task 4 (i = 4):

For task 5 (i = 5):

For task 6 (i = 6):

For task 7 (i = 7):

For task 8 (i = 8):

For task 9 (i = 9):

### Precedence Constraints

These constraints are created according to the technological priority diagram. For each relationship in the diagram, there is a state before a, b. The number of priority constraints will be the number of consecutive relationships and are expressed as follows:

S = {(1,2), (2,3), (3,4), (3,5), (4,6), (5,6), (6,7), (7,8), (8,9)}

0

≤ 0

0

0

≤ 0

≤ 0

≤ 0

≤ 0

### Cycle Time Constraints

The workload of each workstation, that is, the total duration of the work items on that workstation, should not exceed the cycle time. Total number of constraints (K) should be as many as workstations:

For task 1 (k = 1):

For task 2 (k = 2):

For task 3 (k = 5):

For task 4 (k = 6):

For task 5 (k = 7):

For task 6 (k = 6):

For task 7 (k = 7):

For task 8 (k = 8):

For task 9 (k = 9):

#### Cycle Time Formula

### Workstation Constraints

For each workstation, after determining the clusters and values, taking into account the work items that can be assigned to that workstation, the constraints with the following general expression are written for the K workstation:

### 0 or 1 Constraints

### MATLAB Solution

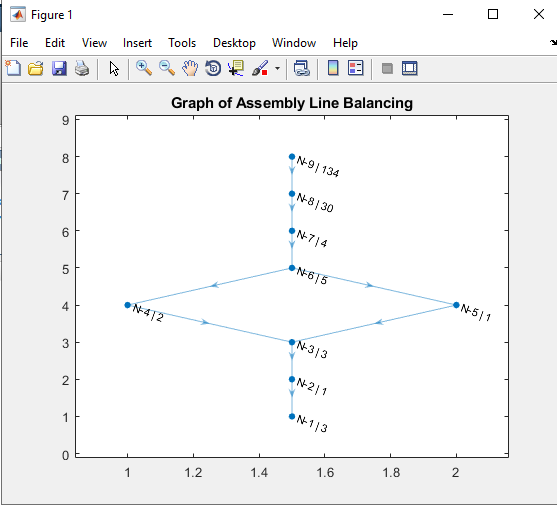


Figure 1 Graph of Assembly Line Balancing

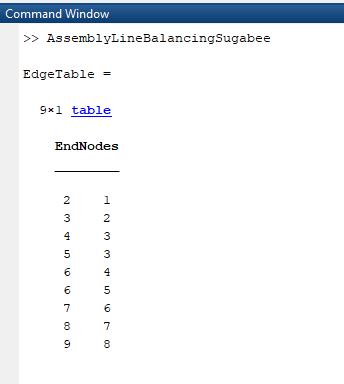


Figure 2 The result of MATLAB Code 2

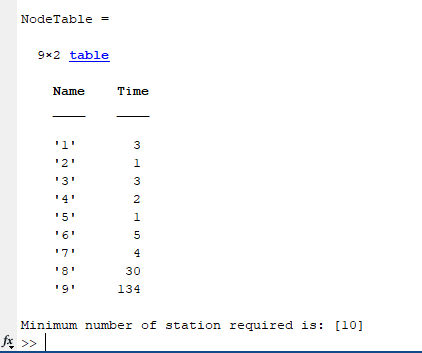


Figure 3 The result of MATLAB Code 2

There are 5 workstations in total on the lollipop line. The total workstation must be 10 to achieve the optimal result.

# CONCLUSION

As a result, the lollipop line was improved by assembly line balancing. Results reached that workstations should be increased by balancing assembly lines. Therefore, associated with the increase of workstations, the other problems in the lollipop line have been resolved and the cycle time has decreased. Through this method, all stages of the process can be observed to produce an efficient work to reduce the loss of time in the observable process and increase the improvement.

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