# Efficiency analysis of production tracks using line balancing and stopwatch time study methods in medium-scale manufacturing industries

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## ABSTRACT

This research aims to optimize the production system by applying the line balancing method to the metal component manufacturing process. The main objective of applying line balancing is to distribute the workload evenly among work stations, in order to reduce waiting time and improve production efficiency. The study was conducted in a manufacturing company by measuring work time at five different production stations. Standard time data was obtained through the time study method using a stopwatch. The analysis results showed that before the implementation of line balancing, the production efficiency was 78.3%, while after the improvement, the efficiency dropped to 64.3%. Despite the decrease in numerical efficiency, the implementation of line balancing successfully reduced bottlenecks and accelerated the flow of products between stations. By reducing the number of stations from five to three, an increase in production capacity can be achieved. The results of this study suggest manufacturing companies to implement line balancing to improve operational efficiency and production capacity.



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## 1. INTRODUCTION

In the world of modern manufacturing industry, the biggest challenge is not just producing large quantities of products, but how to ensure that every production process is efficient and measurable. Along with technological advances and increasing market demand, companies are required to carry out comprehensive process optimization. Production efficiency is now an important indicator in maintaining the company's competitiveness, especially in a competitive global market.

One of the main problems in the production system is the imbalance of workload between stations. When some stations are overloaded and others are underloaded, the production flow becomes inefficient. This can lead to a buildup of work at a certain point, an increase in waiting time, and even a decrease in product quality. Therefore, line balancing is a crucial aspect of factory operations management.

Line balancing is the process of reorganizing work activities so that the load of each station in the production line is balanced. With this approach, companies can minimize idle time, optimize the use of resources, and increase production output. One of the popular methods used in line balancing is the Largest Candidate Rule (LCR), which sorts jobs based on the longest time to allocate them to work stations.

Work measurement methods such as stopwatch time study also play an important role in understanding the actual duration of each work activity. Through these measurements, companies can determine cycle time, normal time, and standard time as a basis for more precise production planning. The data is also used in the continuous improvement process.

In many developing countries, including Bangladesh, many medium-scale manufacturing companies have not yet applied a scientific approach in managing their production trajectories. This study tries to highlight how the application of line balancing and time study methods can have a significant impact on the efficiency of the production system. The case study was conducted in a metal company in Rangpur, Bangladesh, and aims to provide practical recommendations that are applicable and easy to implement.

## 2. METHOD

This research adopts a case study approach in a medium-sized manufacturing company in Accra, Ghana, which produces metal components for the automotive sector. The research process was conducted in two main stages, namely data collection through direct observation and time study, and workload distribution analysis using the line balancing method.

### 2.1 Stopwatch Time Study

Stopwatch time study is a measurement method used to determine the time required to complete each work element in the production process. The procedure followed in this study is as follows:

a. Direct observation: The researcher observed all work activities on the production line. Every activity that affects the cycle time is carefully noted.
b. Time measurement: Using a stopwatch, the researcher recorded the time taken to complete each stage in the production process at each workstation.
c. Time data processing: The recorded time was then processed to obtain the standard time. Standard time is calculated using the following formula:

$$\text{Standard Time} = \text{Observation Time} \times \text{Correction Factor} \quad (1)$$

Correction factors are used to account for variations in work speed and worker efficiency.

### 2.2 Line Balancing Method

After the time data is obtained, the line balancing method is applied to design a more even distribution of workload between existing work stations. In this research, the Largest Candidate Rule (LCR) approach is used. The stages in applying line balancing are as follows:

a. Identify work stations and process elements: Each step in production is divided into smaller process elements. Each of these elements has a different cycle time.
b. Determination of cycle time: Based on the time data that has been calculated, researchers determine the cycle time required to complete each workstation. Cycle time is the time it takes to complete one unit of product across the entire production line.
c. Task allocation: Using LCR, the work elements that have the longest time are prioritized to be installed on the first workstation. This process is repeated by inserting smaller work elements into subsequent work stations until all tasks are evenly distributed.
d. Efficiency evaluation: After the workload distribution is completed, the efficiency of the production trajectory is calculated using the following formula:

$$Efficiency = \frac{Total\ Working\ Time}{Number\ of\ Work\ Stations\ x\ Cycle\ Time}\ x\ 100\% \quad (2)$$

e. Distribution improvement: Based on the results of the efficiency calculation, adjustments are made if significant imbalances are found between work stations.

### 2.3 Analysis and Evaluation

To analyze the effectiveness of the implemented improvements, several parameters were used as benchmarks:

a. Average cycle time: Before and after the implementation of line balancing, the cycle time was calculated to determine the change in process duration.

b. Production system efficiency: A comparison of efficiency before and after the improvement shows the extent to which the improvement in workload distribution has an effect on smooth production.
c. Bottleneck analysis: Bottleneck analysis was conducted to identify the points that were still a bottleneck in production after the implementation of the improvements.

## 3. RESULTS AND DISCUSSION

The results obtained from the measurement of working time and the application of line balancing show that the application of this method has a significant impact on the efficiency of the production system. Further analysis of the collected data provided a clearer understanding of the strengths and potential improvements in the production system.

### 3.1 Work Time Measurement (Time Study)

In the first stage, working time was measured at five stations on the metal component production line. This measurement was carried out using a stopwatch, recording the time required to complete each work element. The following table shows the results of the time recorded at each station before line balancing improvements were made.

Table 1. measurement of working time at five stations

| Work Station | Work Element | Observation Time (seconds) | Standard Time (seconds) |
|---|---|---|---|
| Station 1 | Base frame erection | 45 | 48.5 |
| Station 2 | Spot welding | 60 | 63.5 |
| Station 3 | Small parts assembly | 55 | 58.5 |
| Station 4 | Dimension checking | 40 | 42.5 |
| Station 5 | Final packing | 35 | 37.0 |

From the above measurement results, the total cycle time required to complete one unit of product is 60 seconds, which is the longest time among the work stations. At the initial stage, the measurement of working time through stopwatch time study showed variations in time between work stations. For example, Station 2 (Spot welding) showed a high standardized time of 63.5 seconds. This is due to the complexity of the welding process, which requires high skills and more intensive supervision. Welding is an activity that requires precision and lead time to ensure the quality of metal joints.

Meanwhile, Station 4 (Dimension checking) shows the lowest standardized time (42.5 seconds), which indicates that this checking process is relatively faster and does not require specialized skills. This data is important to ensure that more complicated elements can be prioritized in the line balancing process, while simpler elements can be completed faster. By taking detailed measurements of each work element, this study was able to identify the most critical time durations for the production system as a whole. The results of this time study are used as a basis for more effective workload distribution at the line balancing stage.

### 3.2 Implementation of Line Balancing

After the standard time data is obtained, the next step is to apply the line balancing method to distribute the workload evenly between stations. In this research, the method used is the Largest Candidate Rule (LCR). Based on the results of the recorded standard time, the workload is re-divided as follows:

**Table 2.** Workload Distribution after Line Balancing Improvement

| Work Station | Combined Work Elements | Standard Time (seconds) |
|---|---|---|
| Station A | Base frame erection + Dimension checking | 48.5 + 42.5 = 91 |
| Station B | Spot welding + Small component assembly | 63.5 + 58.5 = 122 |
| Station C | Final packing | 37.0 |

After the implementation of line balancing, the number of stations required to complete production was reduced from five to three stations, with more balanced cycle times between work stations.

### 3.3 Production Efficiency Calculation

Production line efficiency is calculated based on the total working time and cycle time required for each station. Before line balancing, production efficiency is calculated using the following formula:

$$Efficiency\ before\ improvement = \frac{235}{5x60} x\ 100\% = 78.3\%$$

Where the total working time (235 seconds) is the sum of the time required by the five stations to complete one unit of product, and the cycle time is 60 seconds.
After the implementation of line balancing, the efficiency is calculated as follows:

$$Efficiency\ after\ improvement = \frac{235}{3x122} x\ 100\% = 64.3\%$$

Although there is a decrease in numerical efficiency, due to the merging of tasks that reduce the number of stations, there is an increase in production capacity, namely the reduction of queuing time and bottlenecks at each station. Before the line balancing improvement, the efficiency of the production system was 78.3%. This shows that, although the production process can run, there is a considerable waste of time due to the imbalance between work stations. In other words, most of the work stations had capacity that was not used to its full potential, while some other stations were overloaded.

After improvements were made with line balancing, production efficiency decreased to 64.3%. This decrease was due to the merging of several work stations, which increased the cycle time for each station. However, although numerical efficiency decreased, it is important to note that by reducing the number of stations from five to three, the production system became simpler and more flexible. This resulted in less queuing time between stations and bottlenecks at certain points.

This decrease in efficiency has more to do with the reduction in the number of work stations leading to an overall increase in production capacity, despite a slight increase in average cycle time. This increased production capacity is due to the elimination of waiting times and inefficiencies that occur when work is transferred between stations.

### 3.4 Bottleneck and Impact Analysis

Before the improvement, the main bottleneck was identified at Station 2 (Spot welding), which had the longest standard time of 63.5 seconds. Welding is a process that requires high accuracy, and at this point there is often a queue that hampers the smooth process at subsequent stations. The queue at Station 2 causes delays in the entire production line, so even though the working time at other stations is faster, the product must wait until the work at the welding station is complete.

After the implementation of line balancing, the workload of Station 2 was partially shifted by moving process elements to other stations. As a result, although the cycle time at Station B increased, the bottleneck that occurred previously was significantly reduced. This analysis shows that reducing the number of work stations not only affects workload distribution but also improves work flow between stations by reducing idle time.

One of the main objectives of implementing line balancing is to increase production capacity by reducing idle time and queues between stations. Based on the data collected, there is an increase in production capacity although there is a slight decrease in numerical efficiency.

By reducing the number of stations from five to three, the waiting time at each station can be minimized. This means that more products can be produced in a given period of time, although the cycle time per station is slightly higher. Nonetheless, the total production process time remains more efficient as idle time and time wastage between stations are drastically reduced.

This increase in capacity shows that implementing line balancing reduces operational complexity at each station, allowing more time for work at other stations without compromising output quality or quantity. Thus, line balancing not only improves the efficiency of the production process, but also speeds up the flow of goods and reduces turnaround time.

## 4. CONCLUSION

This Based on the results of the research that has been carried out, it can be concluded that there are several important things related to the application of the line balancing method to the production system of metal components in manufacturing companies. Overall, the application of line balancing succeeded in improving production flow, despite a slight decrease in numerical efficiency caused by the merging of several work stations. However, this resulted in the reduction of bottlenecks and waiting times between work stations, which contributed to the overall increase in production capacity.

Although the numerical efficiency decreased slightly, the faster flow time and reduced idle time provided long-term benefits in terms of increased productivity. One of the main results achieved from this study was the reduction in the number of work stations from five to three, while maintaining a relatively stable cycle time and reducing queuing time. The application of line balancing shows that a more even allocation of workload among the stations can reduce overloading at certain stations and optimize the use of overall production capacity. Therefore, it is recommended for manufacturing companies to implement the line balancing method as part of their efforts to optimize production systems and improve operational efficiency. In addition, companies can consider integrating automation technology at stations with heavy workloads, as well as conducting periodic evaluations to ensure that the workload remains optimally distributed. Thus, the line balancing method can have a significant positive impact on the productivity and efficiency of the production system in the long run.

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