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Improvement of Overall Efficiency Using Yamazumi Chart and Heuristic Techniques of a Leather Product Industry

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Abstract

Leather and leather-goods sector of Bangladesh contribute significantly to national exports, but it faces productivity, quality and efficiency constraints continuously. This study mainly focuses on redesigning a leather-wallet industry's assembly line to improve overall efficiency, reduce the idle time and optimize allocation of workstations. Time-study data were collected from an existing production line, and three accepted line-balancing techniques— Kilbridge & Wester Column (KWC), Ranked Positional Weight (RPW) and Largest Candidate Rule (LCR)—were applied to develop alternative assembly line arrangements. Yamazumi bar charts were used to visualize distribution of workload and identify bottlenecks throughout the line. The redesigned models were further evaluated through a separate simulation platform to validate throughput and line performance. The outcomes exhibit that line efficiency improved from 36.65% in the existing system to a maximum of approximately 76%. The optimal workstations' number was significantly reduced, idle time for operator per cycle lessen, and all three models illustrated enhanced balance in simulation, confirming the feasibility of the proposed layout. The findings indicate that applying structured line-balancing and visualization techniques can help leather goods manufacturers ensure daily demand with lessen lead time, fewer workstations and improved efficiency and productivity. This study demonstrates a constructive framework for enhancing production performance in Bangladesh's leather goods industries.

Keywords
Line Balancing, Efficiency, KWC, LCR, Yamazumi Chart.

1. Introduction
Leather industry is an emerging sector in Bangladesh playing a significant role for the economic growth of this country by contributing earning foreign currency as well as impacting in reducing poverty and creating employment. Bangladeshi leather is renowned for its high quality around the globe, however just 0.5% of global leather exports are covered. In the 2020-21 fiscal year, this industry exported leather goods worth a total of $941.6 million, comparing an increase, worth of $797.6 million previous fiscal year. It is essential to ensure effective resource usage to maintain good growth. This sector is categorized into three segments, finished leather, footwear and leather products like wallet, where nearly 157 exporters served wallet to 174 foreign buyers worldwide. Maintaining growth requires optimizing manpower and resource allocation as the production is highly manual labor intensive. Though the demand is high and labor cost is low, this leather sector is struggling with production inefficiencies and poor sequencing in production line. Implementation of Yamazumi Chart and line balancing can optimize the workflows, minimize workstations, and reduce cycle times resulting of enhanced overall productivity and product quality. So, systematic techniques are essential and need to implement, such as line balancing and Yamazumi Chart to eliminate waste, redistribute workloads and maximize production efficiency to meet with the global demand.

1.1 Primary Objective
The primary objective of this study is to redesign and improve the leather wallet factory's existing line with the help of appropriate tools and methodology.

1.2 Specific Objectives of this study
- Improving the overall efficiency of the existing production line.
- Reducing the idle time per cycle time.
- Assigning manpower for new workstations.
- Proposing a better solution model for the existing factory.
- Distributing the workloads among fixed workstations.

2. Literature Review
2.1 Line balancing
Line Balancing (LB) is the process of evenly distributing workload across all processes in a line or value stream process in order to eliminate bottlenecks and excess capacity (Kumar and Mahto 2013). The goal of line balancing is to arrange the individual processing and assembly tasks at each workstation so that the total time required at each workstation is roughly the same (Muhammad and Sarfraz 2017).

2.2 Lean manufacturing
Lean manufacturing is a methodology for getting rid of waste and activities that don't add any value to the product. Waste in the manufacturing process typically takes the form of overproduction, overprocessing, waiting, excessive time used, unnecessary part movement, and excess inventory (Alavi 2003). The lean methodology is supported by a number of different techniques, some of which include Value Stream Mapping (VSM), Kaizen, Six Sigma, Kanban, 5S, Total Quality Management (TQM), Total Productive Maintenance (TPM), Business Process Management (BPM), Visual Management, and others (Bledsoe and Sarah 2013).

2.3 Efficiency
The term "efficiency" refers to a level of performance that describes the utilization of the fewest amount of inputs necessary to accomplish the greatest number of outputs (Balaiya and Maruthu 2018). The ratio of the amount of

outputs produced to the amount of inputs used in the production process is known as productivity (Ahmed and Mafzal 2021).
Efficiency = (Total cycle time∗100)/(Workstation∗Takt time)…(1)

2.4 Cycle Time
Cycle time is the total amount of time spent performing all of the tasks necessary to finish a single operation, measured as the amount of time elapsed between the beginning of one piece being picked up and the beginning of the next (Jain et al. 2016).

2.6 Takt Time
Takt time is a calculation that takes into account both customer demand and the amount of productive time available (Morshed 2014).

2.7 Work Study
Work study is the process of examining the work done in an industry using a consistent system in order to make the greatest possible use of the men, machinery, and materials available in the building at the time (Singh 2016). This method includes 2 parts which are method study and work measurement. Method study is the systematic recording and critical examination of ways of doing things in order to make improvements, whereas work measurement is the application of techniques designed to determine the amount of time required for a qualified worker to complete a task at a specified rate of working (Akkoni and Kulkarni 2019).

2.8 Work Measurement and Time Study
In many firms, work measurement (time and motion study) approaches are used as a best way of enhancing productivity. This involves investigating and minimizing production loss time and improving workers' methods of performing their jobs (Hemanand 2011). A motion and time study are a scientific analysis approach for determining the optimal way to execute a repeated action and measuring the amount of time it takes an average worker to complete a specific task in a fixed workplace. The goal of the motion and time study is to increase workplace productivity and effectiveness (Mohd 2005).

2.9 Productivity and Efficiency Improvement
In this research, work study is associated with a decrease in the production time of ladies' bags. The concept of asking questions and recording the time spent at each workstation has been observed. The research findings demonstrated that employing line balancing approaches increases productivity by 12.71% (Moktadir et al. 2017).

The previous portion of the literature study demonstrated that various lean tools and line balancing approaches were adopted, and as a result, improvements were made in various industries regarding efficiency, quality, production, and other related factors. Cycle time for the existing production line was reduced by removing the non-value-added time, rearranging the operations and designing a new production layout. Many applications are also seen in leather product industry to improve productivity and quality as this sector is not well developed in our country. However, the application of Yamazumi chart and other heuristic methods is found very rarely for the purpose of redesigning an improved line model in the leather and leather product industries. The purpose of this study is to construct the manufacturing line applying the three heuristic approaches, perform a comparison of the solution models, and recommend an optimal solution in order to achieve enhanced efficiency for the existing leather wallet factory.

3. Methods
For improving the efficiency of a production line, line balancing technique is used. For line balancing, different leant tools, heuristic methods, coding are used for getting the maximum improved result. Different methods followed different steps for balancing a line.

3.1 Yamazumi Bar Chart
Yamazumi chart is a man-machine bar chart that shows the total cycle time for each operation when performing their process in the production flow. It is a stacked bar which displays how the cycle time workloads of several operators are distributed, generally in an assembly line or work cell. The Yamazumi chart can be used for an assembly line with one product or multi products. The name direct came from a Japanese word Yamazumi which indicates to stack up. These are merely work balance charts that help with work balancing, the identification and removal of non-value-

added work content, and visually presenting the work content of a set of jobs. In this method, task time for each operation is calculated from time measurement firstly. Secondly, a bar chart is plotted from the calculated time for single operator. The aim of this bar chart is to balance the overall task time for all workstation (Figure 1).

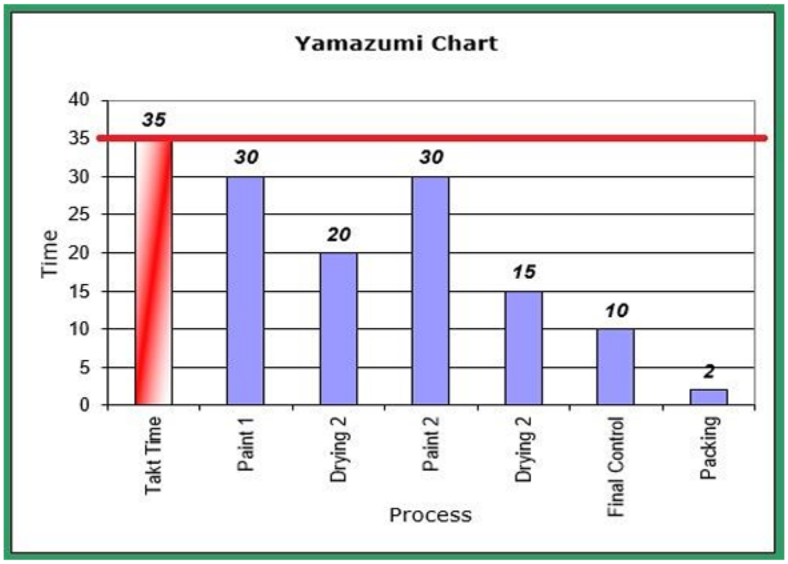

Figure 1. Yamazumi Bar Chart

3.2 Kilbridge and Wester Column Method

Kilbridge and Wester Column method is a heuristic method that select all the work elements according to their position in the precedence diagram for assigning to workstations. Firstly, the work elements from the precedence diagram are divided into columns. Secondly, the work elements are listed into a table according to their columns. For assigning elements to the workstation, start with the first column elements. The assigning process will continue in order of column number until the cumulative time is not greater than the takt time.

3.3 Ranked Positional Weighted Method

RPW is a method in which work elements are distributed among the workstations depending on the work element's time and their position in the precedence diagram. Helgeson and Bernie first introduced this method in 1961. The precedence relationship weights more in this method. For applying this method, for each work element in the precedence, positional weight is determined at first which is the total time on the longest path from that process to last process of the diagram. After that, according to the positional weight, the work element is ranked and sort in a table in descending order. Assigning process follows the rule of KWC method.

3.4 Largest Candidate Rule Method

LCR is a method where the work elements are sort in a descending order into a table according to the highest task time to lowest. This method is mostly popular in textile industries to increase productivity and efficiency. It ensures a bottleneck free flow of processes through the line minimal or no idle time. The work element with largest task time is placed at top of the table and the rest of the element according to the order of their task time. Then the elements are assigned to the workstation as followed in the KWC and LCR method. It is needed to be ensured that the assigning of work element will continue until the sum exceeds the takt time.

4. Results and Discussion

We tested all three heuristic methods on the existing production line and used the Yamazumi Chart to observe the before and after results.

4.1 Results for KWC Model

The results after implementing the KWC technique are as follows:

- The existing production line is redesigned following the steps of this technique. The existing line doesn't include any fixed workstation but the redesigned model contains 14 workstations to distribute the operations.
- The operations are assigned in the workstations according to their task time considering the takt time 70 sec. No bottleneck workstations were found.
- An improved efficiency is seen after the mathematical analysis for this solution model. The numerical analysis showed that the theoretical efficiency increased to 75.91% from 36.65% for the new solution model.
- The balance delay reduced to nearly 30% and the idle time per cycle reduced to 236s.

4.2 Results for RPW Model

The results after implementing RPW technique are as follows:

- The workstations reduced to 14 and all the 43 operations were distributed among the workstations. The steps of RPW were followed properly for line balancing.
- The Yamazumi chart is plotted against the cumulative task time and the new workstations. Here the assignment of workload is balanced and no workstations' cycle time is exceeding the takt time 70 sec in the new solution model. No bottlenecks appear in any station.
- A change is seen in overall efficiency which improved to 75.91% same as the KWC model. The balance delay and idle time per cycle are also reduced same as KWC model.

4.3 Results for LCR Model

The results after implementing LCR technique are as follows:

- The optimum number of workstations found for LCR solution model is 15.
- Here, the Yamazumi chart for LCR solution model is presenting the distribution of workload and the cumulative task time for each new workstation. Takt time for balancing the new line is also 70 sec for this model and no bottlenecks are appearing and no workstations' cycle time is exceeding the takt time.
- The numerical number of improved overall efficiency is 69.9% calculated for LCR solution model. The balance delay and idle time per cycle also reduced in this solution model which are nearly 30% and 316 sec respectively.

4.4 Assigned manpower after line balancing

The existing production line consists of 30 operators for executing all operations whereas in the new models, the number of operators has reduced along with the reduced workstations. For the KWC and RPW solution models, 15 operators were assigned but operators' number increased by one person for the LCR solutions model which is 16 as this model contains one additional station (Figure 2- Figure 4).

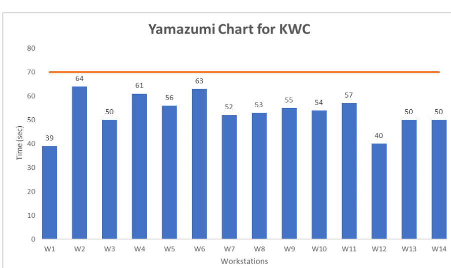

Figure 2. Balanced Graph After Applying KWC Method Method

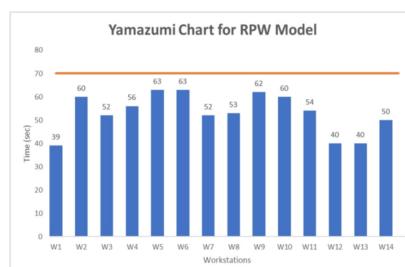

Figure 3. Balanced Graph After Applying RPW

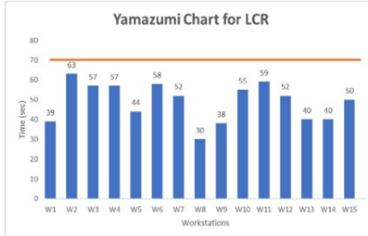

Figure 4. Balanced Graph After Applying LCR Method

4.5 Simulated Results

The simulated results presented the total lead time per day and total output per day for the redesigned production line. The total lead time per day was found to be 24,050sec or nearly 400min for LCR model and 24,369sec or nearly 406min for both KWC and RPW model. New total output per day also increased for all three production lines which are 399pcs, 394pcs and 401pcs for LCR, KWC and RPW model respectively.

5.2 Comparisons of the three solutions

From the comparison it is seen that both the KWC and RPW model have a higher efficiency and reduced balance delay than LCR model. In addition, the number of workstations reduced to 14 for both KWC and RPW model and 15 for LCR model. After running the simulation, the RPW model showed the highest output per day, which is 401pcs whereas the KWC and LCR model showed the output of 394pcs and 399pcs respectively (Table 1).

Table 1. Resultant Data Before and After Line Balancing

	Line Efficiency %age	Balance Delay %age	New Workstations	Total Lead Time in Line in min	Number of Output per day
Existing	36.65	63.34	29	432	370
LCR	69.9	30.1	15	400	399
KWC	75.91	24.08	14	406	394
RPW	75.91	24.08	14	406	401

6. Conclusion

The study highlights that the leather industry is a big deal for Bangladesh's economy, but it's really struggling with how things are run on the ground. Most factories are stuck using old methods, which is why we see efficiency sitting at a low 36.65%. Because everything is done by manual labor, a messy production line just leads to wasted time and way too much money spent on labor. Analysis represents that if we use tools like Yamazumi charts and line balancing, the change is massive. By testing the RPW (Ranked Positional Weight) model, they managed to jump from that low starting point to 76% efficiency. From the simulation result it is found that the total output per day for the solution models is 394pcs and 399pcs for KWC and RPW models respectively whereas total output per day is found 401 pcs for RPW model. It shows that RPW model is providing the highest output. What's even better is that they cut the workforce in half—from 30 people down to 15—while making more products up to 401 pieces a day.

7. Recommendations

- Though different heuristic methods are used in this study, other heuristic methods, lean tools, generic algorithms and other algorithms can be used to improve the efficiency and redesign the existing line.
- Other leather products like footwear, ladies' bags etc. producing company can implement these line balancing techniques to obtain an optimal balanced line and optimal workstations.
- These techniques can be implemented in any product-based company like seat belt, light bulb, fan etc. manufacturing company.
- These techniques can be used for balancing mix model assembly line.

- Other simulation software like arena simulation can be used for simulation purposes.

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