

# **Real-Time Mobile Labor Sewing Line Balancing For Garment Production Factory**

**Pavee Siriruk and Sirintorn Pengsiri**

Industrial Engineering Department, System Engineering Department  
Suranaree University of Technology, Thailand  
pavee@sut.ac.th, m6501624@g.sut.ac.th

## **Abstract**

This study aims to develop a real-time mobile application-based production line balancing tool for export garment factories in Thailand, addressing the challenges posed by significant market demand. Thailand's garment factories export OEM sportswear outfits to Europe, America, and Japan, adapting products to meet ever-changing fashion trends. Consequently, production and delivery times are significantly shorter than traditional seasonal fashion cycles. Making changes to color and sizing throughout the season puts even tighter constraints on production schedules. Therefore, the manufacturer that can most swiftly adapt to fluctuating demands for the combination of colors, sizes, and styles will capture the largest market share. The case study of sport ware outfit manufacturer is considered. The plant is experiencing decreased productivity resulting from suboptimal line configurations and the ongoing learning curve of the workforce. Overloaded tasks or worker skill gaps can create bottlenecks that slow down overall production. The engineering team conducted an analysis to pinpoint the specific process or resource causing the production slowdown. This analysis involved a line-balancing process using stopwatch timing and spreadsheet calculations to determine the time consumption of each process step. The results were visualized in a bar graph format known as a Yamazumi chart. Subsequently, reducing the total time represented by all bars in the Yamazumi chart is necessary to achieve the desired overall time reduction. To replace manual stopwatches and spreadsheet-based line balancing, we developed a digital mobile tool equipped with an algorithm for automated line balancing analysis. Our real-time mobile tool drastically reduces line balancing operation time from four hours to under ten minutes. Bottleneck elimination resulted in a substantial boost to production efficiency, increasing it from 70.4% to 76.3%. This represents a notable 5.9% improvement.

## **Keywords**

Line Balancing, Takt time, Yamazumi Chart, Production Lead Time, Real-Time Mobile Tracking.

## **1. Introduction**

The ready-made garment industry for export from Thailand is worth tens of billions of baht. is about to face uncertainties resulting from the global market. These uncertainties stem from both economic conditions and climatic factors that can cause damage to the clothing industry. Challenges arise in terms of raw materials and supply chains. Additionally, changing fashion trends influenced by an increase in global tourism or the impact of new-age influencers from online communities may make outdoor fashion more popular. However, intense competition among leading brands will accelerate the growth of Fast Fashion, favoring those who can quickly adapt to consumer demands. This inevitably affects the supply chain. The garment factory plays a crucial role in responding to the ever-changing demands and requirements of the ready-made fashion industry. One key criterion for measuring responsiveness to change is the total time in production, known as the Production Lead Time. This time is further subdivided into Takt time, which represents the time per completed garment, and Cycle Time, which accounts for the time spent at each production step. Given that garment production involves numerous steps (typically averaging 20-40), it's essential to balance and align work methods across these stages. This ensures smooth operations and avoids bottlenecks, which are points where work slows down significantly. To identify bottlenecks, the Yamazumi Chart is a valuable tool. It graphically displays the Cycle Time for each production process as a bar graph, allowing clear comparisons. By adjusting processes based on this data, we can optimize production toward a Lean approach. To balance workload and

optimize cycle times as displayed in the Yamazumi chart, industrial engineers employ line balancing techniques. This involves equalizing the work duration at each process step. Traditional line balancing methods, involving manual timing, data analysis, and graph creation, are time-consuming, complex, and often yield suboptimal results due to dynamic work conditions. By the time balance is achieved, workforce changes may render the analysis obsolete. This research introduces a Real-Time Mobile Labor Sewing Line Balancing system for Thailand's garment export industry. The system employs digital tools and mobile applications to capture real-time process data, perform on-the-fly calculations, and visualize results as bar graphs. This empowers engineers to make immediate adjustments to operations, validate improvements, and achieve target Takt Time, ultimately enhancing efficiency and reducing line balancing efforts.

## **2. Literature Review**

### **Industry 4.0 Elements for Garment Production Line**

Jayawickrama et al. (2019) have developed a prototype that demonstrates a smart production line for apparel manufacturing that leverages Industry 4.0 technologies to capture cycle times, balance workloads, and create Yamazumi work balance charts. By accurately measuring cycle times, utilization rates, and worker involvement, production management can gain valuable insights into actual production performance, which is often difficult to achieve in traditional settings.

### **Line Balancing in the Production Environment**

S M Atikur and Tamanna (2023) Uncertainties in demand can lead to imbalanced utilization and capacity, resulting in decreased productivity and increased costs. To address these challenges, garment industries must implement efficient tools for optimizing resource utilization. Line balancing techniques, which aim to distribute workloads evenly and eliminate bottlenecks, have proven effective in improving line efficiency and productivity, as demonstrated in case studies.

### **Balance Production line on IE method**

Cheng and Li (2020) By applying industrial engineering principles to analyze and improve the production line, this research focused on balancing workloads, measuring productivity, and calculating associated metrics such as the balance rate and loss index. The results demonstrated a significant increase in the balance rate and a decrease in the balance index after the implementation of improvements.

### **Lean 4.0 for cycle time collection and Yamazumi analysis**

Joao et al. (2023) By combining lean manufacturing principles with Industry 4.0 technologies, manufacturers can significantly enhance their overall efficiency and gain a competitive edge. The Yamazumi chart, a valuable tool for analyzing production cycle times and identifying bottlenecks, traditionally relies on manual data collection, which can be time-consuming and error-prone. Automated cycle time data collection approaches, coupled with real-time Yamazumi chart generation, provide management with valuable insights into the manufacturing process. Research has demonstrated the effectiveness of this solution in improving understanding of the relationships between workstations and their impact on overall line performance.

### **Workstation solution for line balancing problem**

Qidong et al. (2021) Line balancing is a critical aspect of assembly process planning but achieving optimal results using commercial solvers can be challenging. This research explores the unique characteristics of the line balancing problem and proposes a workstation-oriented strategy for job assignment. By implementing the developed algorithm on benchmark datasets, the effectiveness and efficiency of the solution were verified.

### **Productivity Improvement using Motion and Time study**

Mohmoud et al (2023) The research focused on addressing production challenges in garment factories by narrowing the gap between actual and target output. By applying motion and time study techniques, the study aimed to optimize production processes and achieve maximum efficiency. The results demonstrated a significant increase in production quantity and efficiency, exceeding 15%.

### **Simulation for Balancing of Assembly Line**

Musharaf and Xiao-jun (2022) The efficiency of a production line is heavily influenced by its balance, which requires an even distribution of workload among workstations to avoid bottlenecks and maintain a smooth workflow. This study focuses on balancing the assembly line in the automotive industry, addressing the management's concern of

unequal job allocation and resulting idle time. The optimized assembly line, both in its current and proposed forms, is verified using Arena software.

### **3. Research Methodology**

#### **Principles of Line Balancing.**

Line balancing is a strategy in production that involves aligning worker tasks and machinery to match production rates with the Takt Time and the capabilities of the work process. The goal is to achieve a relatively continuous and consistent flow in the production process. When the production time matches the Takt Time, the production line is well-balanced that idle time will be eliminated as every workstation is working continuously without waiting for others. Consequently, bottlenecks are minimized, ensuring a smooth and uninterrupted flow of work.

#### **Key concepts and terms in Garment Production:**

- **Takt Time:** The basic concept in line balancing is Takt Time. It represents the available production time per unit of output needed to meet customer demand. In simpler terms, it's the maximum time a product can spend at each workstation to keep up with customer orders.
- **Cycle Time:** It is the time between a piece entering into the system and the following. It is also the time that is available at each station to perform the assigned tasks.
- **Man:** The number of workers on the production line who successfully complete the cycle time check at each workstation.
  - **BN:** Bottleneck refer to the workstation with the longest cycle time within the entire process line of the garment production.
  - **EFF:** Efficiency is calculated as the ratio of standard produced minutes to actual spent production minutes.
  - **SAM:** Standard allowed minutes in the garment manufacturing industry represents the time required to produce one finished garment, including various allowances, as of the formular:

$SAM = \text{Basic Time} + \text{Bundle Allowances} + \text{Machine and Personal Allowances}$

- **% Balance:** The calculation of Cycle time value and Man value to understand the ratio of how the time consume in each workstation compare to final balanced cycle time, as of the formular:  
 $\% \text{ Balance} = (\text{Total Cycle Time} \times 100\%) / (\text{Cycle Time max} \times \text{Man})$
- **Bottleneck Output:** The production output quantity that can produce from the maximum cycle time of the bottleneck workstation, as of the formular:  
 $\text{BN Output} = 60 (\text{min}) / \text{CTmax} = \text{pcs./hr.}$
- **%Bottleneck Efficiency Actual:** The efficiency ratio of the actual output from the bottleneck workstation compared to standard allowance minute (SAM), as of the formular:  
 $\% \text{BN EFF Actual} = ((\text{Actual Output} \times \text{SAM}) / (\text{Man} \times 60)) \times 100$
- **%Bottleneck On Time Planning:** The comparison ratio of the standard output to the actual output from the bottleneck workstation to understand how close of the actual production to the target planned based on standard takt time, as of the formular:  
 $\% \text{BN OTP} = \text{Takt Time} / \text{CT max} \times 100$

### **3.1 Line Balancing Analysis Process and Calculation**

#### **The garment process line**

A typical garment production line consists of 20 to 40 workstations, each performing a unique task sequentially. Worker skills vary across stations, and daily bottlenecks often arise due to inconsistencies in adherence to work standards. Line balancing involves identifying and addressing bottleneck stations that impede production efficiency. The process begins with analyzing actual cycle times and comparing them to standards using a Yamazumi chart to pinpoint bottleneck workstations.

The goal of line balancing is to eliminate bottlenecks and create a smoother flow of output by leveling the workload across workstations. This involves relocating tasks, redistributing work among workers, or adding additional staff to bottleneck areas. While reskilling or intensive training for bottleneck workers can be effective but may require more time than other solutions.

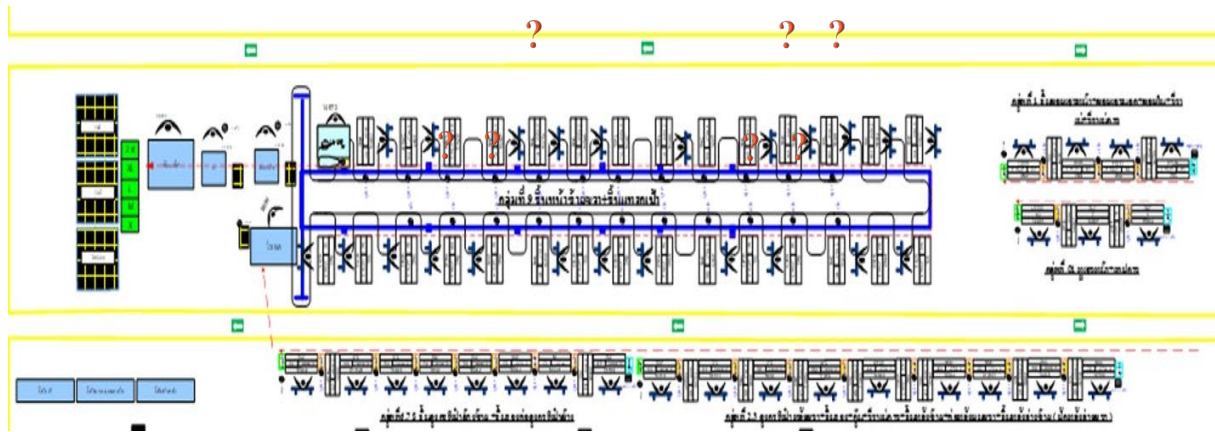


Figure 1. Sewing Assembly Line

A balanced line enables production to run at a higher speed without interruptions. The cycle times for all processes will be more consistent with the standard, as evidenced by a flatter Yamazumi chart. This indicates that the maximum process cycle time has been reduced to approach the target.

### Yamazumi Chart



Figure 2. Yamazumi Chart and Line Balancing Application

### 3.2 The Calculation Formulas

The principle of Line Balancing is the process of distributing workload evenly across workstations to meet production requirements within the specified takt time. This process encompasses data calculation to determine the bottleneck, which is then validated against the target takt time using the formulas provided below.

Balance ratio is a measure of optimized performance that evaluates how evenly work is distributed across workstations. It is calculated by comparing the total production cycle time to the longest cycle time and the total worker who recorded it.

$$\% \text{ Balance} = (\text{Total Cycle Time} \times 100\%) / (\text{Cycle Time max} \times \text{Man})$$

- Bottleneck Production Line Efficiency calculated by actual output and standard time by total number of workers.

$$\% \text{BN EFF Actual} = ((\text{Actual Output} \times \text{SAM}) / (\text{Man} \times 60)) \times 100$$

- Bottleneck On Time Planning calculated by comparing takt time by cycle time max.

$$\% \text{BN OTP} = \text{Takt Time} / \text{CT max} \times 100$$

### 3.3 Line Balancing Analysis Process

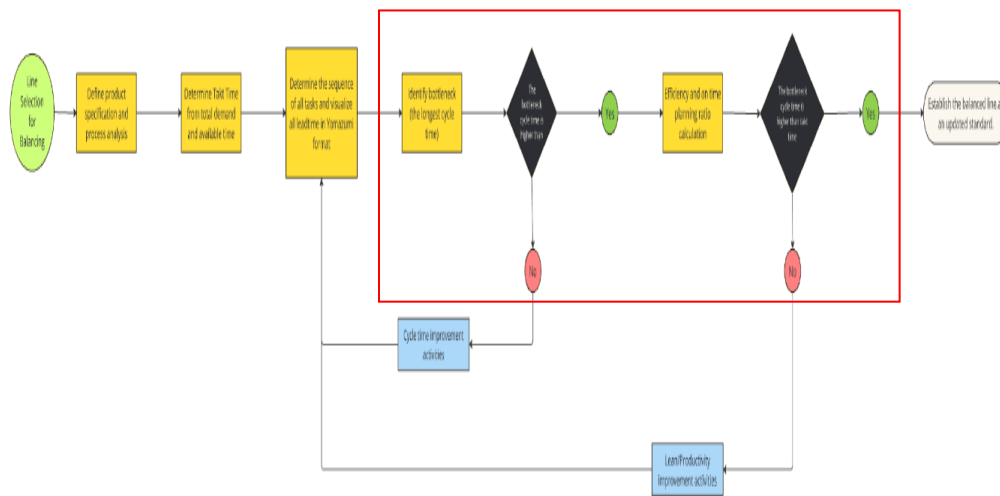


Figure 3. Line Balancing Analysis Process

The Line Balancing Analysis process for manual methods begins with defining the product and process to be balanced. The sequence of operations is determined, and cycle time standards and targets are set. Each workstation is then time-checked to identify bottlenecks, which are addressed through improvement programs. The action outlined in the red square can be facilitated by a mobile application software. After balancing the process, we can assess its performance by calculating the total cycle time, maximum cycle time, and the number of workers involved. To determine efficiency, we compare actual output to the standard output based on time and manpower usage. Finally, we can evaluate overall efficiency by comparing takt time to the maximum cycle time.

### 3.4 Production Line Efficiency Improvement

Process improvement aims to optimize workload distribution and balance working time among different processes by streamlining tasks or adjusting the sequence of work. The following actions are implemented to achieve these goals:

- To improve bottleneck workstations, identify operations with the longest cycle times and reduce them to meet the standard target.

- To split bottleneck operations, consider redistributing tasks from operations with higher cycle times to lower cycle times.
- To optimize short processes, identify tasks that can be divided into smaller, more manageable components and allocate them to other less time-consuming operations.
- To streamline the process, consider combining operations with lower cycle times.

### 3.5 System Architecture

The system architecture depicted here represents a research case study at VT Garment factory in Thailand, with branch factories located in remote areas within Thailand and Myanmar. Communication between these sites is facilitated through a VPN structure over the internet. The master application system and database server are housed on a premise server at the Bangkok headquarters in Thailand. Intra-network connectivity is established via LAN cables and Wi-Fi interfaces between the master server PCs and other mobile devices

#### 3.5.1. Mobile Application key features

- ‘Line Balancing’ to track and record the working cycle time of each worker.
- ‘GSD Analysis’ to track and record the working cycle time of each operation.
- ‘OK/NG Card’ to keep a record Photo/Data of products OK or NG all operation.

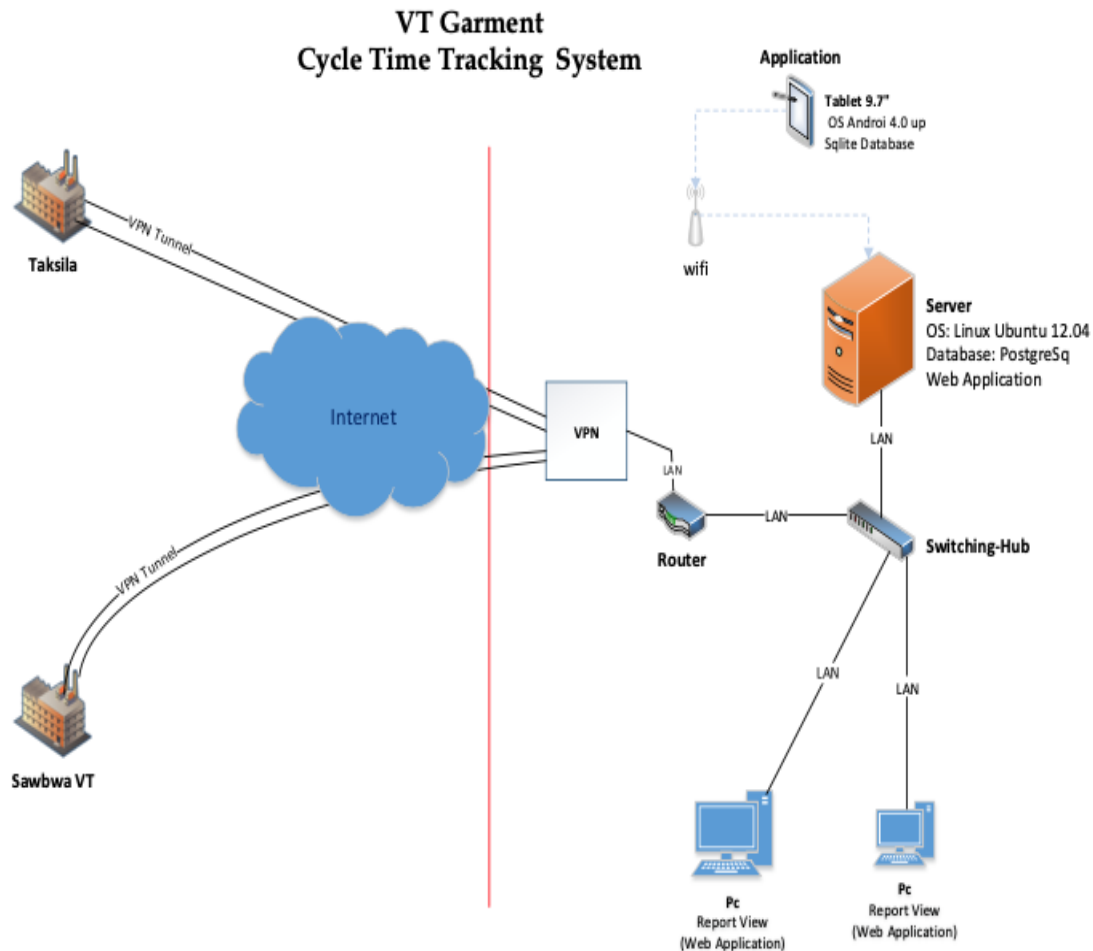


Figure 4. System Architecture

## Application Model and Features



Figure 5. Line Balancing Application Module

### 3.5.2. Web Application key features

- 'Import Data' to import GSD data from XLS files to be the system database.
- 'Line Balancing Report' to generate the Line Balancing pre-designed report.
- 'GSD Analysis Report' to generate the GSD Analysis pre-designed report.
- 'OK-NG Card Printing' to print out OK or NG card as recorded in database.
- 'User Management' to manage all users and Tablet in which registered in the system.

## 3.6. Research Process

### 3.6.1 Product and process assessment

Conduct a comprehensive evaluation of products to determine which ones significantly contribute to profit, considering factors such as sales volume and total avenue. Subsequently, perform an in-depth analysis of the processes that enhance the value of these high-impact products.

### 3.6.2. Define productivity and Loss analysis

From the selected products, determine the productivity factors contributing to problem areas, Using these lean wastes as a framework, identify the process step with the longest cycle time as the primary improvement target.

### 3.6.3. Formulate Line Balancing terms and formulas

Key garment production concepts and terminology will be translated into line-balancing formulas. These formulas will then be integrated into a digital application for bottleneck identification.

### 3.6.4. Determine the tasks sequence and visualize it in the Yamazumi chart

Classify the target product's processes into sequential tasks. Conduct time studies on each task using a digital time recording mobile application. Subsequently, the application will plot the recorded time data on a Yamazumi bar chart to visually compare process durations and identify the process consuming the most time relative to the required takt time.

### 3.6.5. Develop Mobile-Web Application and System Architecture

To achieve desired productivity, line balancing formulas will be established to pinpoint bottlenecks based on takt time standards. Mobile and web applications will be created to support flexible production, and system architecture will be optimized for the specific production environment and resource constraints.

### 3.6.6. Test Run and Data Validations

To improve productivity, the application was tested extensively against system and software requirement, considering user input. The testing process involved multiple iterations to precisely identify and validate bottleneck improvement. Data accuracy was verified by random sampling of bottleneck tasks.

## 4. Results and Discussion

Based on the research, the primary focus area for enhancing the line balancing process with the mobile application are shortened recording process and significant reduction in analysis time with improved algorithms. The traditional method of using a stopwatch and performing calculations in a spreadsheet required over 3 hours, in contrast, the

mobile application can streamline this process, completing it in less than an hour. Another crucial factor is workforce allocation, which varies depending on whether the line balancing process occurs overnight or across shifts.

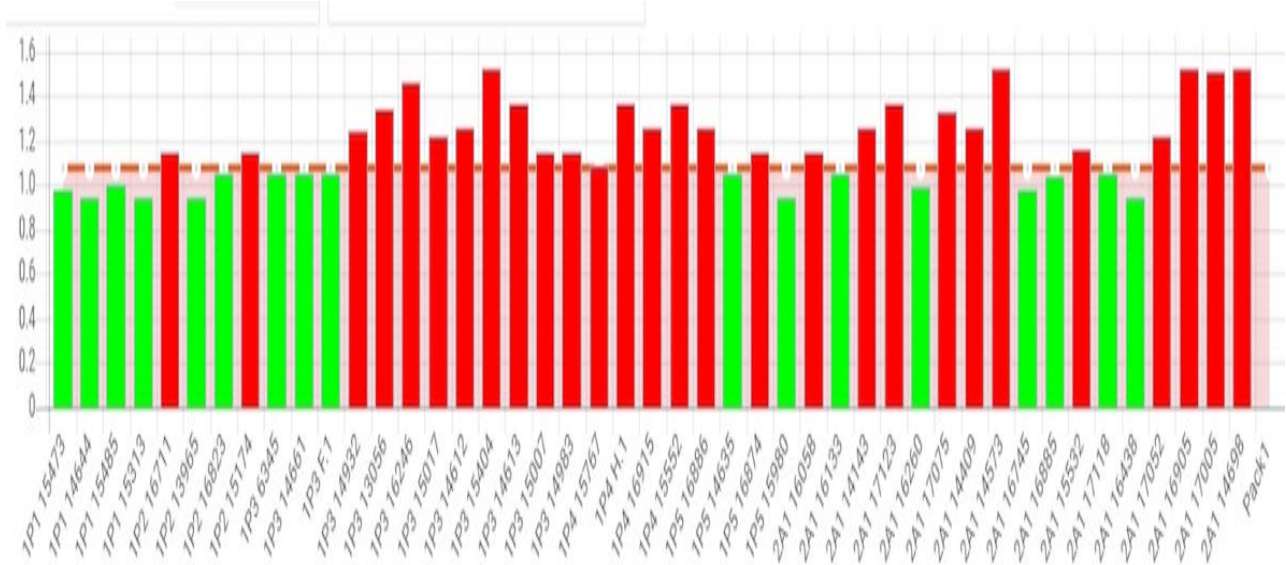


Figure 6. Unbalance Line (Before improvement)

The outcome of production efficiency enhancement was achieved by identifying and eliminating bottlenecks through line balancing and relocation activities. This resulted in a decreased cycle time, leading to an overall production efficiency increase from 70.4% to 76.3%, or a 5.9% improvement.

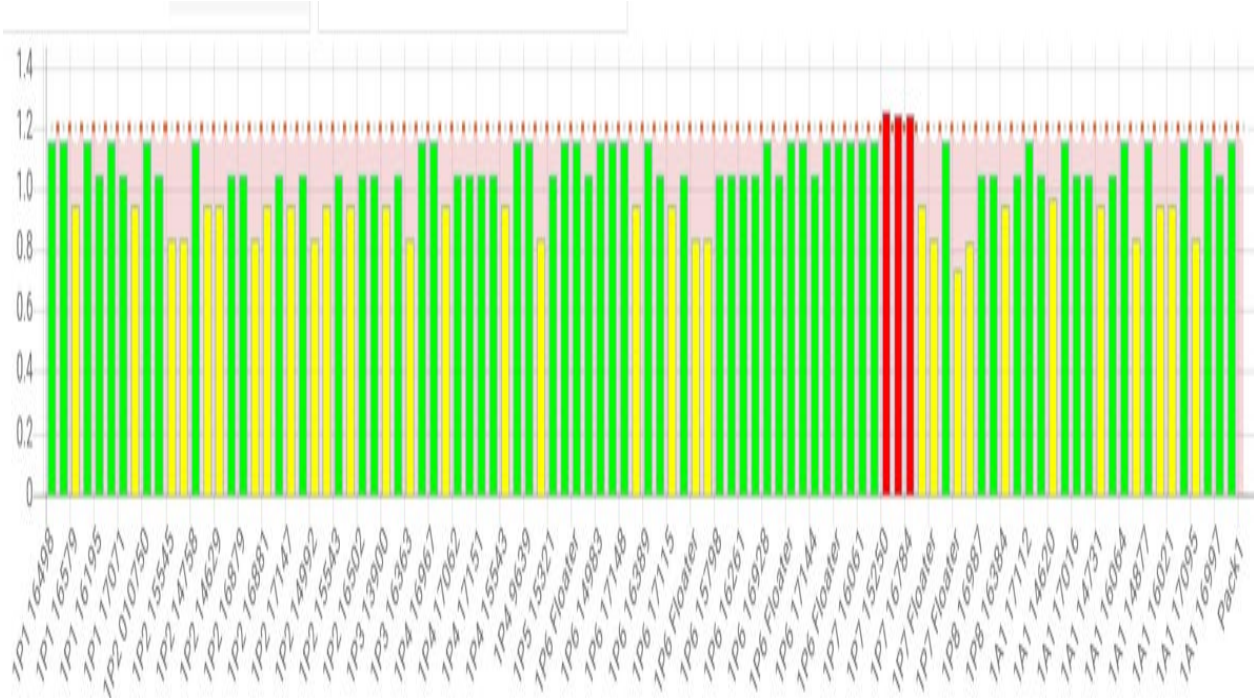


Figure 7. Balance Line (After improvement)

## **5. Conclusions**

To address the increasing need for high productivity, short lead time, and rapid market response, a line balancing tool accessible via mobile and web applications has been tested and deployed in a Thai garment factory. Transitioning from manual paperwork to digital processes necessitates a financial outlay. However, this investment is justifiable given the potential for increased productivity, as evidenced by 5.9% improvement in the test case. Moreover, ongoing efforts to identify and eliminate bottlenecks represent a significant opportunity to enhance profitability.

## **References**

- Jayawickrama U., Imalka K., Ranga A., Simulation for Balancing of Assembly Line using Heuristics: A Case Study of Automotive Manufacturing Industry, Moratuwa Engineering Research Conference (MERCon) 2019
- S M Atikur R., Tamanna K., A Simulation-Based Approach for Line Balancing under demand uncertainty in production environment, Winter Simulation Conference, 2023.
- Cheng P., Li Y., Research on Balance Improvement of Mobile Phone Production Line of A Company Based on IE Method, International Conference on Wireless Communications and Smart Grid (ICWCSG), 2020.
- Joao P., Gil G., Rui P., Anabela R., Lean 4.0: A Digital Twin approach for automated cycle time collection and Yamazumi analysis., Proc. Of the International Conference on Electrical, Computer, Communications and Mechatronics Engineering (ICECCME), 2023.
- Qidong Y., Xiaochuan L., Jie S., Lei Z., A Workstation Solution Based Heuristic Algorithm for Assembly Line Balancing Problem, Chinese Control and Decision Conference (CCDC), 2021.
- Mohmoud Z. M., Rahaf A. A., Ala'a M., Sumaia Al-I., Improving the Productivity Rate and Ergonomic Requirements using Motion and Time Study, 9<sup>th</sup> International Conference on Optimization and Applications (ICOA), 2023.
- Musharaf S., Xiao-jun L., Simulation for Balancing of Assembly Line using Heuristics: A Case Study of Automotive Manufacturing Industry, IEEE 6<sup>th</sup> Advanced Information Technology, Electronic and Automation Control Conference (IAEAC), 2022.

## **Acknowledgment**

This research was successfully completed with the support and assistance of various individuals and organizations. I would like to express my gratitude to everyone involved in this project.

First and foremost, I would like to extend my heartfelt thanks to my advisor, Assistant Professor Dr. Pavee Siriruk, for his invaluable guidance, advice, and encouragement throughout this research. He has generously dedicated his time to reviewing and refining the content of this research to ensure its completeness.

I would also like to thank the faculty members of the Department of Systems Engineering for providing knowledge, understanding, and useful recommendations that were instrumental in developing this research. My gratitude extends to the committee members for their helpful suggestions, which contributed to the completion of this work.

I am deeply grateful to Mr. Chalumpol Lotharakpong, Managing Director of V.T. Garment Co., Ltd., and his team for providing data and facilitating the data collection process. This opportunity allowed me to conduct research in a real-world setting and gain firsthand experience.

I would like to express my sincere appreciation to Mr. Thasit Sriprang, Project Consultant at Extra Solution Engineering Co., Ltd., for his comprehensive support in all aspects—providing encouragement, understanding, and assistance in various matters. His support has been crucial in enabling me to successfully complete this research.

Finally, I would like to thank my friends and others who are not mentioned by name for sharing their knowledge, opinions, and encouragement during this research. I hope this study will be beneficial to those who are interested and can be applied to further studies or practical applications in the future.

## **Biographies**

**Pavee Siriruk** received a Ph.D. (2009) in industrial and systems engineering from Auburn University, Auburn, AL. He is a lecturer in the Department of Industrial Engineering at Suranaree University of Technology, Nakhon Ratchasima, Thailand. His research focuses on stochastic processes, system optimization, supply chain, and logistics.

**Sirintorn Pengsiri** received a Bachelor of Industrial Technology in Industrial Engineering Technology (B.Ind.Tech) (2022) degree in industrial engineering technology from Kasem Bandit University, Bangkok, Thailand. She is the Founder of The Integrator Company Limited an automation system integration consultancy service.