

A Bi-Objective Optimization Model for Real-World Task Allocation in RMG Sewing Lines: Capacity Maximization and Minimization of Capacity Loss

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Abstract

A data-driven approach for task allocation can significantly improve sewing line efficiency by ensuring that the workload is evenly distributed among operators based on their individual skill level and speed, thereby reducing non-productive time and optimizing machine utilization. This balanced allocation minimizes the accumulation of work-in-progress (WIP) at specific stations. Our approach is to develop an optimization model that dynamically assigns tasks to operators, with the objective of minimizing total line completion time and maximizing line efficiency. Our methodology involves collecting real-time performance data (e.g., individual operator efficiency, task processing times) and feeding it into a Heuristic Optimization Algorithm (e.g., based on queueing theory and operator skill matrices). This algorithm dynamically recommends the optimal task assignment to balance the line. Improvement after using this approach is expected to be a significant increase in line efficiency (e.g., 10-15%) and a reduction in production lead time. The implication of this approach is a paradigm shift towards a smart, flexible manufacturing system in the Bangladeshi garment industry, enabling faster response to market demands and enhancing global competitiveness through better resource utilization.

Keywords

Elective Course Prediction, Elective Course Recommendation System, Correlation Among Courses, and Core Course Result Prediction.

1. Introduction

The Ready-Made Garments (RMG) industry is the largest driver of Bangladesh's economy, contributing 10-12% to GDP and generating over 81.29% of the country's total earnings (Rafique & Islam, 2025). The sewing line is the most critical part of the garment manufacturing process, as it directly determines a factory's productivity, workflow efficiency, and output capacity. Unbalanced operations, improper layout, and bottlenecks in the swing line, which reduce productivity, as seen in a study, productivity falls to nearly 71% (Santos, n.d.). Improving the sewing line directly enhances the overall efficiency because it removes bottlenecks and reduces unnecessary motion and delay. Studies show that when the sewing line is optimized, the output and efficiency improve significantly. A study on the garment industry shows increased daily production from 184 to 387 pieces and raised efficiency from 29.1% to 50.4% through balancing the sewing line (Gelaw, 2021a). Despite a strong contribution to Bangladesh's economy, the RMG sector is struggling with inefficiencies such as poor productivity, long production lead times, high costs, and low first-time accuracy (Hasan et al., 2022). These issues not only reduce the overall performance but also raise concerns for global customers relying on Bangladeshi manufacturers. Farjana et al. (2022) addressed that the RMG industry faces a major challenge as the lead time for sourcing raw materials is significantly longer than the lead time for exporting

finished products (Chowdhury & Keya, 2022). Unequal distribution of tasks among workstations leads to bottlenecks, idle time, and low line efficiency (Gelaw, 2021b). Traditional scheduling methods often ignore human factors such as skill variability, worker fatigue, and ergonomic needs, resulting in suboptimal resource utilization and worker dissatisfaction (*Optimal Workforce and Machine Scheduling to Maximize Profit and Worker Satisfaction | IEEE Conference Publication | IEEE Xplore*, n.d.). Poorly balanced assembly lines increase work-in-progress (WIP), waiting times, and production costs (Lu, 2025). Most optimization algorithms focus on mathematical efficiency, neglecting real-world constraints like urgent orders, machine breakdowns, and worker variability (*Enhancing Garment Manufacturing Efficiency through Human-Centered Scheduling | Production Engineering*, n.d.). Our approach focuses on the real-world problem of task allocation. In the garment industry, task allocation is focused on maximizing the capacity that can be achieved and minimizing the loss of capacity. Though there are a number of studies on optimizing task allocation but there is a clear gap in addressing the real-world scenario, while our study is focused on developing an optimization model to address the real-world problem while considering the interface preference of the industry personnel.

1.1 Objectives

The objectives of this research are:

- Developing an optimization model to allocate tasks, focusing on:
 - Capacity maximization
 - Minimization of Capacity Loss
- Developing an optimization model interface suitable for industry use.

2. Literature Review

In this section, prior studies on the garment industry are analyzed to provide key findings and gaps. Halim et al. (2025) conducted research in a garment manufacturing company, specifically the denim jacket assembly line of XYZ Group, to optimize production efficiency through a comparative analysis of line balancing techniques (Halim et al., 2025). Their study focused on the sewing and assembly department of the apparel industry, where inefficient task distribution and imbalanced workstations had resulted in low line efficiency (51.05%). To address this, Halim and colleagues applied three heuristic approaches, Ranked Positional Weight (RPW), Largest Candidate Rule (LCR), and the computerized COMSOAL method, to redesign workstation allocations while maintaining precedence constraints (Halim et al., 2025). Through time study, SMV calculation, precedence diagram construction, and iterative workstation redistribution, they evaluated improvements in efficiency, balance delay, and smoothness index (Halim et al., 2025). Among the methods, COMSOAL produced the most effective results, achieving 91.6% efficiency, reducing workstations from 27 to 15, and minimizing balance delay to 8.4%, indicating that probabilistic and simulation-based balancing techniques can significantly enhance workflow uniformity and productivity in garment assembly lines (Halim et al., 2025). Xie et al. (2021) conducted research in a garment manufacturing factory to enhance the balancing of apparel assembly lines, particularly when parallel workstations are introduced into the line configuration (Xie et al., 2021). Their study focused on the sewing department, where workload variation, mismatched task-operator skills, and labor-division inefficiencies commonly occur in complex apparel production environments. To address these issues, Xie and colleagues developed an Improved Ant Colony Optimization (IACO) algorithm with a dual-pheromone system designed to optimize both workload smoothing and efficiency loss of labor division (ELLD) during task allocation in parallel workstation settings (Xie et al., 2021). Using real production data from shirt, jacket, and suit lines, the algorithm assigned tasks based on precedence constraints, operator skill level (OSL), operator proficiency (OP), and workstation capacity while automatically determining when to create parallel workstations (Xie et al., 2021). Their experiments demonstrated that the IACO approach significantly outperformed supervisor-based traditional balancing solutions, achieving lower smoothness indices, reduced inefficiencies in labor division, and improved line arrangement efficiency, particularly for complex apparel such as jackets and suits, where parallel workstations yield substantial performance gains (Xie et al., 2021). Ahamed et al. (2024) conducted research in the garment manufacturing industry of Sri Lanka to examine how predictive analytics can be utilized to optimize production efficiency (Ahamed et al., 2024).

Their work focused on the production planning and control function, where decision-making related to labor management, Standard Minute Value (SMV), work-in-progress (WIP), and overtime plays a critical role in operational performance (Ahamed et al., 2024). Using a systematic literature review of 30 relevant studies, they analyzed the influence of data-driven forecasting on garment manufacturing processes and assessed the challenges associated with data preprocessing and model reliability (Ahamed et al., 2024). Their approach highlighted the potential of advanced

predictive techniques, particularly ensemble-based models and multi-model analytical frameworks, to improve forecasting accuracy and operational decision-making (Ahamed et al., 2024). They also identified limitations such as short time-series datasets that restrict the ability to capture seasonal production patterns. The authors concluded that integrating predictive analytics with time-series analysis can significantly enhance production forecasting, enabling the garment industry to strengthen efficiency and remain competitive in global markets (Ahamed et al., 2024). Lu (2025) conducted research in a shirt production line within a garment manufacturing enterprise to address inefficiencies caused by uneven task distribution, bottleneck operations, and long production cycles (Lu, 2025). Focusing on the sewing workshop, the study applied industrial engineering methods—including time study, standard minute calculation, 5W1H analysis, and ECRS principles—to rebalance processes, optimize workstation allocation, and eliminate bottlenecks (Lu, 2025). Through these methods, Lu reconfigured work elements, merged tasks, and redesigned bottleneck stations. The optimized approach significantly improved performance, increasing the line balance rate from 39.5% to 62.8%, reducing imbalance loss, and lowering the smoothness index, demonstrating the effectiveness of industrial engineering techniques in enhancing garment production efficiency (Lu, 2025). Koç and Eryürük (2025) conducted research in a large-scale apparel manufacturing factory in Türkiye to develop a digitalized sewing line-balancing system that dynamically assigns operators and optimizes workload using real-time data from process monitoring devices (PMDs) (Koç & Eryürük, 2025).

Their study focused on the sewing department, where fluctuating order sizes and varying product styles create bottlenecks and workload imbalances. Using a parallel-station position-weighted algorithm integrated with live performance data, the authors automated operator-task allocation and balanced station workloads. Their approach—combining digital lean principles, IoT-based PMDs, and heuristic balancing—resulted in significant improvements: line efficiency increased from 79.68% to 88.31%, and per-operator productivity rose by 10%, demonstrating the effectiveness of digital real-time balancing in improving sewing line performance (Koç & Eryürük, 2025). Teshome et al. (2024) conducted research in the Abay Garment Industry in Gondar, Ethiopia to improve the productivity of a polo shirt sewing line by addressing severe workload imbalances and bottlenecks across 29 sewing operations (Teshome et al., 2024). Their work focused on the sewing and assembly department, where unequal operator workloads, long queue times, and inefficient resource use were preventing the factory from meeting its production target. Using simulation-based line balancing with the Arena software—supported by time study, SAM calculation, precedence mapping, and scenario testing—they developed several improved line configurations. Their approach identified bottleneck operations (e.g., collar attach, side seam) and tested scenarios involving task merging, resource reallocation, and added capacity. The final optimized scenario increased output from 293 to 381 units, raised line efficiency from 39.06% to 55.64%, improved labor productivity from 54.25% to 66.8%, and reduced labor cost by 15.63%, demonstrating the effectiveness of simulation-driven line balancing in garment production (Teshome et al., 2024).

Katirae et al. (2023) conducted research in manual assembly manufacturing environments to develop a bi-objective Assembly Line Worker Assignment and Rebalancing Problem (ALWARBP) model that accounts for workers' differences in expertise and perceived physical effort (Katirae et al., 2023). Their study focused on the assembly department, where heterogeneous worker skills, physical strain, and frequent workforce changes create challenges for maintaining balanced lines. Using a linear programming model with ϵ -constraint optimization, the authors integrated worker-dependent task times, ergonomic constraints based on the Borg scale, and the possibility of using trainers to support inexperienced workers. Applied to three industrial case studies, their approach demonstrated that incorporating trainers and ergonomic considerations significantly improves feasible rebalancing outcomes and helps managers achieve better trade-offs between cycle time and task reassignment requirements (Katirae et al., 2023). Thao et al. (2023) studied the knitted garment industry to formalize and optimize sewing line balancing, replacing manual balancing with a structured digital approach using the HUST method and BSL-HUST software (Thao et al., 2023). Focusing on the sewing department, they applied algorithmic techniques (Simulated Annealing, Binary Search) to improve task grouping, cycle-time control, and overall line efficiency across real factory production lines (Thao et al., 2023). Despite extensive research on sewing line balancing, most studies optimize efficiency under ideal or mathematical assumptions, overlooking real-world challenges such as urgent orders, variable worker skills, capacity loss, and practical usability in Bangladesh's RMG sector. Therefore, a clear gap exists for a real-world, industry-oriented optimization model that minimizes capacity loss while aligning with the interface preferences and operational needs of factory personnel.

3. Methods

This study was focused on developing a user-friendly interface for industry personnel in order to make data-driven decisions while allocating workers to tasks in a sewing line based on their hourly capacity. This study comprises five main stages: data collection & preparation, preparation of the Capacity Matrix, Development of a bi-objective optimization model, Development of a user-friendly Interface for industry personnel, and Comparison of the allocation with the existing intuition-based allocation method. The following flowchart illustrates the overall flow of this study (Figure 1).

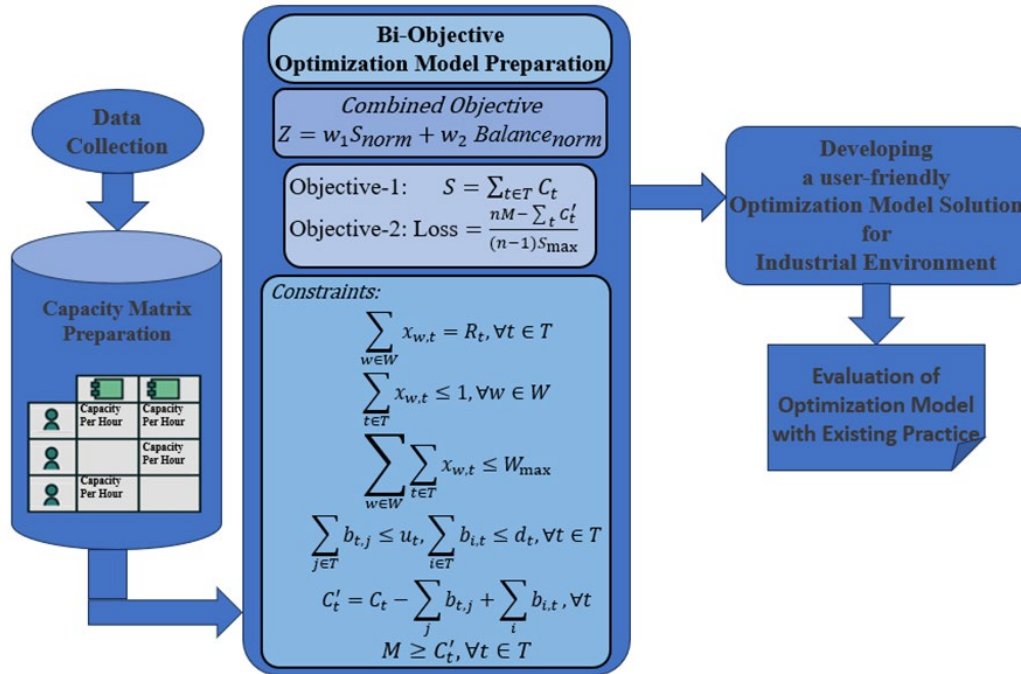


Figure 1. Methodology overview

3.1 Data Collection & Preparation

In this research, the hourly capacity for each task for each worker was collected from multiple sewing lines of a reputed garments company. The data was collected in terms of how much time the workers take per piece of their given task. Then, by adding 5% allowance for necessary non-value-added tasks, the hourly capacity was calculated for each worker and task. For example, worker W1 takes 39 seconds to join a single sleeve to a garment's body. Then, adding 5% allowance for the necessary non-value-adding tasks, it becomes 40.95 seconds. And thus the hourly capacity for worker W1 is 87 pieces. It should be noted that the data was collected for 5 pieces, and then the mean of the data was taken for further calculations.

3.2 Capacity Matrix Creation

The collected data is then utilized to create a capacity matrix. The capacity is expressed for every worker in terms of how many pieces a worker can do in a certain task. For example, worker W1 can join 87 sleeves in one hour. As there was no specific capacity matrix maintained in the company, the capacity data was collected from 20 sewing lines of each consisting of an average of 25 workers. This made the size of the capacity matrix 555 rows representing 555 workers' data.

3.3 Bi-Objective Optimization Model Formulation

By consulting with the concerned person, it was determined that the decisions of allocation revolve around 2 main objectives. One is to maximize the overall capacity of the sewing line so that the sewing line can meet the predetermined target set by the higher authority. And another objective was to minimize the capacity loss percentage for the sewing line after allocation, so that the non-utilized talent waste can be minimized. In order to achieve the

minimization of the capacity loss percentage, the capacity support approach is practiced in the industry. In this approach, if after allocation for any task the allocated capacity fails to meet the target capacity, the task with surplus capacity then provides support to the task with deficit capacity. The practical implementation is done in a way that the line supervisor brings the product to the worker with surplus capacity, thus rebalancing of capacity minimizes the capacity loss percentage.

3.4 Optimization Model Formulation for Worker Allocation and Line Balancing

In this study, the allocation of sewing operators to task stations is formulated as a constrained multi-objective optimization problem. The objective is to simultaneously maximize total operational capacity and minimize the imbalance across tasks while respecting all operational and resource constraints. The model incorporates task-specific worker requirements, operator skill heterogeneity, and post-allocation capacity balancing through inter-task support.

1. Sets, Parameters, and Input Structure

Let,

- $T=\{1,2,\dots,n\}$ denote the set of tasks,
- $W=\{1,2,\dots,m\}$ denote the set of available workers.

The following parameters are given:

- $y_{w,t}$: the capacity contribution of worker w if assigned to task t , obtained from the Capacity Matrix.
- R_t : required number of workers for task t .
- W_{max} : maximum number of workers allowed for assignment.
- C^* : target capacity per task.

2. Decision Variables

The allocation is determined using the following variables:

- $x_{w,t} \in \{0,1\}$: = 1 if worker w is assigned to task t , and 0 otherwise.
- $b_{i,j} \geq 0$: amount of support transferred from task i to task j during balancing.
- $u_t = \max(0, C_t - C^*)$: surplus capacity at task t .
- $d_t = \max(0, C^* - C_t)$: capacity deficit of task t .
- C'_t : final balanced capacity of task t .

The raw allocated capacity before balancing is computed as

$$C_t = \sum_{w \in W} x_{w,t} y_{w,t}$$

3. Model Constraints

i. Task Worker Requirement

Each task must receive exactly its required number of workers:

$$\sum_{w \in W} x_{w,t} = R_t, \quad \text{for all } t \in T.$$

ii. Worker Uniqueness

A worker can be assigned to *at most one* task:

$$\sum_{t \in T} x_{w,t} \leq 1, \quad \text{for all } w \in W.$$

iii. Total Worker Availability

Total assigned workers cannot exceed the allowable workforce:

$$\sum_{w \in W} \sum_{t \in T} x_{w,t} \leq W_{max}.$$

iv. Support Flow Feasibility

Balancing flows must respect available surplus and required deficit:

$$\sum_{j \in T} b_{t,j} \leq u_t, \sum_{i \in T} b_{i,t} \leq d_t, \quad \text{for all } t \in T.$$

v. Balanced Capacity Definition

$$C'_t = C_t - \sum_j b_{t,j} + \sum_i b_{i,t}, \quad \text{for all } t \in T.$$

vi. Maximum Balanced Capacity Bound

A global balancing bound M satisfies:

$$M \geq C'_t, \quad \text{for all } t \in T.$$

4. Multi-Objective Optimization

The study considers two objectives:

i. Maximization of Total Allocated Capacity

$$S = \sum_{t \in T} C_t,$$

normalized by the theoretical upper bound S_{\max} :

$$S_{\text{norm}} = \frac{S}{S_{\max}}.$$

ii. Minimization of Capacity Imbalance

Imbalance is quantified using:

$$\text{Loss} = \frac{nM - \sum_t C'_t}{(n-1)S_{\max}}.$$

A normalized measure of balance is:

$$\text{Balance}_{\text{norm}} = 1 - \text{Loss}.$$

iii. Combined Weighted Objective

The final optimization goal is expressed as:

$$Z = w_1 S_{\text{norm}} + w_2 \text{Balance}_{\text{norm}},$$

Where, $w_1 + w_2 = 1$ and $w_1, w_2 \geq 0$.

This scalarization enables the simultaneous optimization of production throughput and line balance, providing a flexible trade-off controlled via the weights.

The model integrates worker capability profiles, task-specific workforce requirements, capacity balancing mechanisms, and dual optimization objectives. It ensures feasibility under practical constraints while attaining an optimized allocation that improves both productivity and operational uniformity. This framework is used to evaluate the dataset and guide the subsequent heuristic and computational analyses.

3.5 Development of a user-friendly Optimization Model Solution in Excel-VBA

The developed bi-objective optimization problem is then implemented on an Excel VBA environment. Visual Basic for Applications (VBA) was used to create a custom Tab Button to address the optimization problem in Microsoft Excel.

The custom Excel VBA button accesses the capacity for each task from the capacity matrix sheet by utilizing the mixed integer programming model for the allocation of workers. The VBA code takes the total number of workers that can be allocated, the minimum number of workers needed for each task, the target capacity for the sewing line, and the weight to be assigned to each objective. The VBA code utilizes the solver tool for the allocation of workers.

3.6 Evaluation of Output

The output of the optimization model and the current practice were compared on the basis of the smoothness & conformance to the target of the capacity graph before and after balancing, and the capacity loss percentage.

The smoothness of the capacity graph represents the work-in-progress(WIP) inventory; the smoother the line, the lower the WIP. And the conformance to the target represents that it can meet the demand. And the smoothness of the capacity graph before balancing represents that it needs less balancing, thus saving time for balancing.

And the capacity loss percentage represents the non-utilized talent. If the capacity loss percentage is lower, it means that it has utilized its talent efficiently.

4. Results and Discussions

The primary objective of this research was successfully achieved through the design and deployment of a bi-objective optimization model. This model aims to maximize total line capacity and minimize capacity loss percentage. To ensure accessibility and practical application within the industrial setting, the proposed solution was rendered usable through an Excel VBA interface. The effectiveness of the model was validated by comparing its allocation results against the existing intuition-based practice.

The quantitative improvements are summarized in Table 1 below, based on the study data:

Table 1. Comparison of Results between intuition-based current practice and Optimization-based solution

	<i>Current Practice (Before Optimization)</i>	<i>Proposed Model (After Optimization)</i>	<i>Improvement</i>
<i>Plan Target (Capacity)</i>	<i>140 pieces/hour</i>	<i>188 pieces/hour</i>	<i>+34.3%</i>
<i>Capacity Loss %</i>	<i>49.48%</i>	<i>32.00%</i>	<i>-17.48%</i>

The findings and discussion of this research strongly support the core objective that an intuition-driven worker allocation method can be successfully transformed into a data-driven process using a bi-objective optimization model. This model is designed to maximize line capacity and minimize capacity loss, and it was implemented using an Excel VBA interface, which is suitable for the industrial environment. Comparative analysis shows that the model increased the Plan Target Capacity from 140 pieces/hour to 188 pieces/hour, representing a significant 34.3% increase. Simultaneously, it reduced the Capacity Loss rate from 49.48% to 32.00%. These results prove that a significant amount of Unutilized Talent previously existed within the workforce due to inefficient allocation strategies, which the model successfully leveraged.

Meeting the target capacity is an emergency requirement for a sewing line, as failure instantly creates pressure on production management and leads to the accumulation of Work-In-Progress (WIP) inventory. In the current practice, the capacity graphs clearly show that some tasks fail to reach the target capacity, resulting in lower overall capacity (Figure 2).

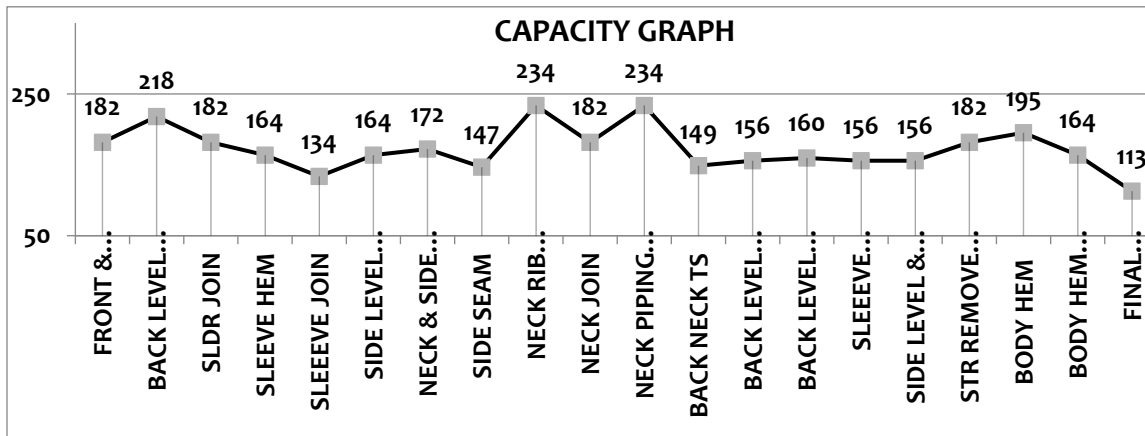


Figure 2. Capacity Graph of Current Practice before Balancing

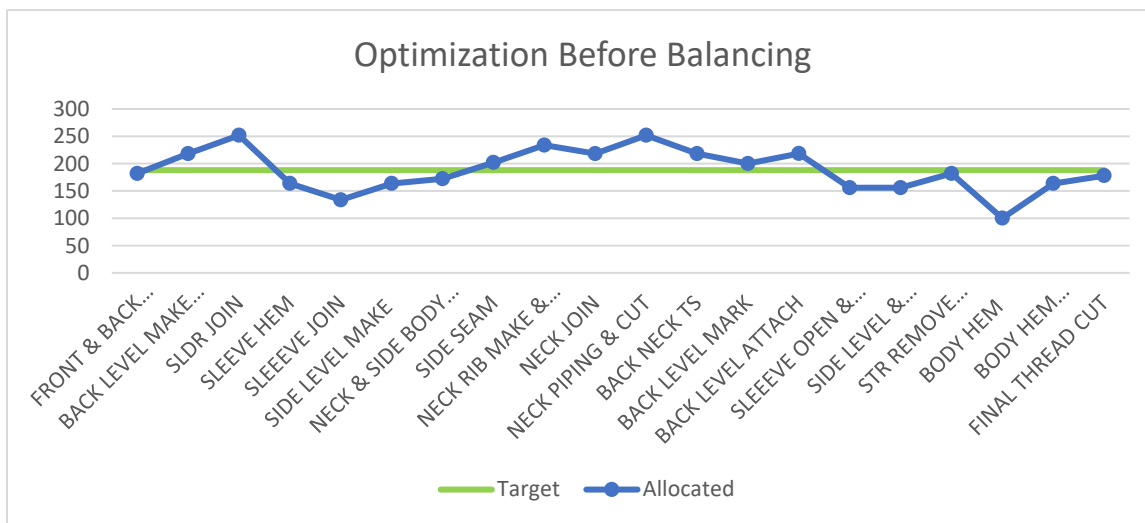


Figure 3. Capacity Graph of Optimization before Balancing

These Figures 3,4,5 show that, before optimization, there was a large difference in capacity between task stations; some were high-capacity while others acted as Bottlenecks. The final output of the line is determined by this Bottleneck. This is why Capacity Balance is essential; it ensures a smooth and uninterrupted flow. The high Capacity Loss (49.48%) meant that worker talent was Not Utilized. The optimization model addresses this problem using a Capacity Support mechanism. In this process, the surplus capacity from faster workers is mathematically distributed to support the slower, deficit stations (e.g., "6.2 pcs of support by W22"). This dynamic rebalancing ensures that every processing step achieves a balanced capacity of 188 pieces/hour, thereby avoiding Bottlenecks and reducing Unutilized Talent.

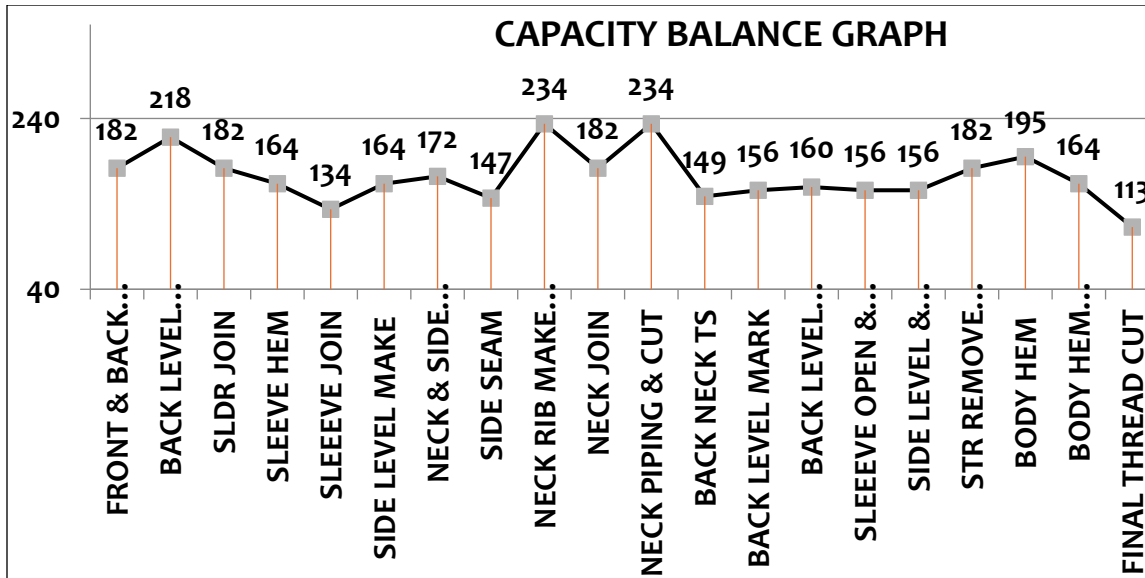


Figure 4. Capacity Graph of Current Practice after Balancing

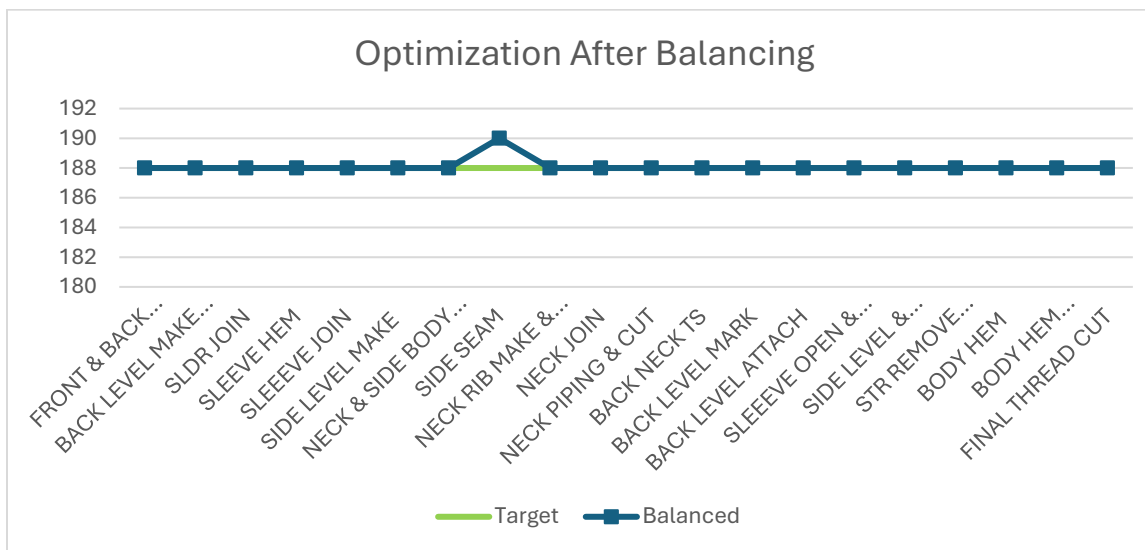


Figure 5. Capacity Graph of Optimization after Balancing

The most critical finding relates to the "smoothness" of the production flow. In the current practice, large variances existed between task stations; some had high capacities (e.g., 218 pieces/hr), while others acted as severe bottlenecks (e.g., 65 pieces/hr). In a sewing line, the output is determined by the bottleneck. The inability to meet the target capacity creates an emergency situation in the factory, leading to the rapid buildup of Work-In-Progress (WIP) inventories. To prevent this, Capacity Balance is essential.

The optimization solution addresses this through a Capacity Support mechanism. This system mathematically distributes surplus capacity from faster stations (e.g., "6.2 pcs of support by W22") to tasks with a capacity deficit. The resulting optimized line is significantly smoother than the current practice graph, ensuring an uninterrupted flow of products and minimizing WIP inventory.

The Implication or relevance of this research is that it provides an industry environment-friendly solution for the Bangladesh Ready-Made Garment (RMG) sector. Since most industrial floors are heavily reliant on Microsoft Excel for data management, embedding the complex MIP (Mixed-Integer Programming) algorithm behind a simple "Custom

Tab Button" links advanced theoretical optimization with practical shop-floor application. This is a high-impact solution to improve efficiency, empowering production managers to make real-time, data-driven decisions and optimize the entire line's throughput without the need for new software training.

5. Conclusion

In the context of Bangladesh's garment industry, Excel is still the main tool used for data analysis, even though many previous research studies have used Python for similar analytical work. This research fulfills its main objectives with the help of a bi-objective optimization model designed and solved with a convenient Excel-VBA interface tool. The results show that there is a measurable difference in performance when an intuition-driven allocation strategy is replaced with a data-driven solution.

Moreover, the tool is able to increase the target capacity of the line from 140 pieces per hour to 188 pieces an hour with a reduction in capacity loss from 49.48% to 32%. This will reduce the potential bottleneck and talent underutilization on the line because the system is able to create a balanced line by facilitating support between tasks. For the Bangladesh Ready-Made Garment (RMG) sector, this tool offers an industry environment-friendly solution, a high-impact solution to improve efficiency. It empowers production managers to visualize worker capability and assign tasks in a way that optimizes the entire line's throughput rather than just individual stations.

While the current model relies on static hourly capacity data, future research could integrate dynamic variables. Incorporating worker fatigue rates over the course of a shift could lead to more realistic capacity planning. The integration of real-time sensor data (IOT) could allow the model to dynamically rebalance the line during production runs, further enhancing responsiveness to unforeseen disruptions.

References

- ahamed, Z., Asanka, D., & Rajapakse, C., "Optimizing Production Efficiency in the Garment Industry: The Role of Predictive Analytics Techniques in Sri Lanka's Textile Sector," *Proc. 8th SLAAI International Conference on Artificial Intelligence (SLAAI-ICAI)*, pp. 1–6, 2024. <https://doi.org/10.1109/SLAAI-ICAI63667.2024.10844970>
- Chowdhury, F. Y., & Keya, A. J., "Readymade Garments Exports from Bangladesh: Challenges and Possible Way-Out," *International Journal of Business and Management*, vol. 17, no. 7, pp. 19–28, 2022. <https://doi.org/10.5539/ijbm.v17n7p19>
- "Enhancing Garment Manufacturing Efficiency through Human-Centered Scheduling," *Production Engineering*, Springer, 2025.
- Gelaw, Y. A., "Experimental Study and Improving the Productivity of Assembly Line Balancing in Teleja Garment Manufacturing in Ethiopia," *Engineering Preprints*, 2021. <https://doi.org/10.20944/preprints202112.0365.v1>
- Gelaw, Y. A., "Experimental Study and Improving the Productivity of Assembly Line Balancing in Teleja Garment Manufacturing in Ethiopia," *Preprints*, no. 2021120365, 2021. <https://doi.org/10.20944/preprints202112.0365.v1>
- Halim, A., ISLAM, M. A., & AHMMED, M. S., "Optimizing Denim Jacket Assembly: Comparative Analysis of Line Balancing Techniques for Efficiency Improvement," *World Journal of Advanced Research and Reviews*, vol. 25, no. 2, pp. 1664–1680, 2025. <https://doi.org/10.30574/wjarr.2025.25.2.0559>
- Hasan, S., Khan, G., Hoque, M. R., Hassan, F., & Ahmed, N., "Lean Practices in the Bangladeshi Ready-Made Garments Industry and Global Significance," *International Journal of Logistics Research and Applications*, vol. 25, no. 3, pp. 309–327, 2022. <https://doi.org/10.1080/13675567.2020.1847262>
- Katirae, N., Calzavara, M., Finco, S., Battaia, O., & Battini, D., "Assembly Line Balancing and Worker Assignment Considering Workers' Expertise and Perceived Physical Effort," *International Journal of Production Research*, vol. 61, no. 20, pp. 6939–6959, 2023. <https://doi.org/10.1080/00207543.2022.2140219>
- Koç, B., & Eryürük, S. H., "Optimizing Sewing Line Balancing in Apparel Manufacturing through Digitalization," *Fibres & Textiles in Eastern Europe*, vol. 33, no. 1, pp. 10–26, 2025. <https://doi.org/10.2478/ftce-2025-0002>
- Lu, Q., "Research on Balance Optimization of Garment Production Line Based on Industrial Engineering Methods," *Scientific and Social Research*, vol. 7, no. 2, pp. 164–174, 2025. <https://doi.org/10.26689/ssr.v7i2.9666>
- "Optimal Workforce and Machine Scheduling to Maximize Profit and Worker Satisfaction," *IEEE Conference Proceedings*, IEEE, 2019.

- Rafique, R., & Islam, M. R., “Economic Impact, Challenges, and Recommendations of Ready-Made Garment (RMG) Industry in Bangladesh,” *Business Review and Case Studies*, vol. 6, no. 1, pp. 100–100, 2025. <https://doi.org/10.17358/brcs.6.1.100>
- Santos, D., “Productivity Improvement in a Sewing Line through Garment Manufacturing Company in the Philippines,” unpublished work.
- Teshome, M. M., Meles, T. Y., & Yang, C.-L., “Productivity Improvement through Assembly Line Balancing by Using Simulation Modeling: A Case of Abay Garment Industry Gondar,” *Heliyon*, vol. 10, no. 1, Article e23585, 2024. <https://doi.org/10.1016/j.heliyon.2023.e23585>
- Thao, P. T., My, P. T. L., & Phan, D.-N., “State Problem of Balancing Sewing Line of Industrial Knitted Products,” *Fibres and Textiles*, vol. 30, no. 2, pp. 26–33, 2023. <https://doi.org/10.15240/tul/008/2023-2-003>
- Xie, Z., Du, J., Chen, Q., & Wang, X., “Enhancing the Labor Division in the Balancing of Apparel Assembly Lines with Parallel Workstations through an Improved Ant Colony Algorithm,” *Journal of Engineered Fibers and Fabrics*, vol. 16, Article 15589250211055784, 2021. <https://doi.org/10.1177/15589250211055784>

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