

Implementation of Total Productive Maintenance (TPM) by Evaluating Overall Equipment Effectiveness (OEE): A case study

Tanzil Ahamed

Department of Industrial Engineering
BGMEA University of Fashion & Technology
Dhaka 1230, Bangladesh
222-030-651@buft.edu.bd

Md Ariful Ferdous

Department of Industrial Engineering
BGMEA University of Fashion & Technology
Dhaka 1230, Bangladesh
ariful.ferdous@buft.edu.bd

Rakibul Islam Rakib

Department of Industrial Engineering
BGMEA University of Fashion & Technology
Dhaka 1230, Bangladesh
222-013-651@buft.edu.bd

Seemanta Sarker Pranta

Department of Industrial Engineering
BGMEA University of Fashion & Technology
Dhaka 1230, Bangladesh
222-018-651@buft.edu.bd

Abstract

Maximizing equipment utilization is important to maintain productivity and cost competitiveness in high-tech production. Overall Equipment Effectiveness (OEE) is a well-known parameter to evaluate equipment performance effectively. However, existing studies focus on determining OEE instead of presenting structured, evidence-based strategies for improvement. Moreover, there is limited research showing how specific Total Productive Maintenance (TPM) pillars directly influence the OEE components within automated & process-heavy industries. This study assesses OEE performance in a selected high-tech production facility and applies some targeted TPM actions to resolve the identified losses. A systematic methodology was adopted, comprising process-level data collection, OEE computation, Six Big Losses analysis, TPM deployment, and post-implementation evaluation. Primary analysis revealed low availability and performance across vital processes, resulting in OEE values between 63% and 75%, which fall below the 85% standard. Through analysis, loss patterns, Autonomous Maintenance, Planned Maintenance, and Focused Improvement were implemented to reduce breakdowns, stabilize cycle times, and eliminate minor stoppages. Post-implementation results show clear improvements, which confirms that organized TPM deployment

reduces unplanned downtime and improves operational stability. This research provides practical, data-based evidence on how effective TPM is at improving OEE. It also offers a framework that can be used for ongoing equipment performance improvement in high-tech manufacturing.

Keywords

OEE, TPM, High-Tech Industry, Six Big Losses.

1. Introduction

Manufacturing industries that depend on complex production systems must keep their operations stable and efficient in this age of competition. As demand is increasing and production is becoming more automated, even minor problems with equipment can impact the output and overall productivity. Many manufacturers keep track of equipment losses since they can increase quickly. Manufacturers use Overall Equipment Effectiveness (OEE) to observe how efficiently their machines perform, as OEE integrates availability, performance rate, and the quality of output into one clear measure. Although generally accepted industrial standards set a benchmark around 85 percent, many facilities find it difficult to reach this level. Frequent breakdowns, inconsistent operating speeds, and recurring defects often keep OEE values below the expected standard. While OEE is widely measured, simply calculating the number does not address the issues behind it. Much of the current research shares OEE results but provides little advice on how to turn those results into real improvements. In everyday manufacturing operations, efficiency can decline for several reasons. These include unexpected equipment malfunctions, short delays, and uneven material flow in the manufacturing process. These patterns show the need for an approach that can find the true causes of OEE loss and offer solutions that bring long-term improvement instead of temporary fixes. Total Productive Maintenance (TPM) can provide a structured approach to increase reliability, stabilize performance, reduce downtime, and losses from defects. Though TPM is broadly recognized, research on the effects of specific TPM practices on Overall Equipment Effectiveness (OEE) in complex manufacturing settings still lacks. Many studies do not clearly establish the link between detailed loss diagnosis and the improvement actions taken. This study examines OEE performance in a high-tech manufacturing facility. It identifies major loss factors using the Six Big Losses framework. For processes with OEE below the accepted industrial standard of 85 percent, we apply TPM techniques to reduce the breakdowns, improve performance stability, and to decrease waste from defects. Therefore, the effectiveness of these actions by using post-implementation OEE results to determine the level of improvement was monitored. The study provides practical insights on integrating OEE evaluation and TPM in a structured manner. It also shows observed operational data which demonstrates how focused maintenance activities results into measurable changes in equipment behavior. These insights support manufacturing organizations in improving reliability and productivity of a process, especially when equipment performance is a big factor.

1.1 Objectives

1. To calculate the current Overall Equipment Effectiveness (OEE)
2. To identify the major sources of OEE losses
3. To implement Targeted Total Productive Maintenance (TPM) strategies
4. To evaluate the improvement in OEE following TPM implementation
5. To provide recommendations for sustaining and further enhancing OEE

2. Literature Review

Recent advancements in manufacturing research continue to position Overall Equipment Effectiveness (OEE) as a central metric for evaluating equipment-level productivity, due to its ability to integrate availability, performance, and quality into a single indicator of operational efficiency (Thürer *et al.*, 2023). Contemporary studies maintain the world-class threshold of approximately 85 percent as a key benchmark for competitive performance, while the Six Big Losses framework remains the dominant structure for identifying the fundamental sources of inefficiency across industrial equipment. Within this framework, losses related to breakdowns, setup and adjustment, idling and minor stoppages, speed reduction, startup defects, and production rejects are recognized as the major contributors to OEE deterioration, particularly in automated or cycle-sensitive environments. Total Productive Maintenance (TPM), supported by its eight structured pillars, continues to be regarded as the primary strategic approach for reducing these losses, improving equipment stability, and ensuring operator involvement in sustaining long-term performance improvements.

Recent empirical research highlights a renewed emphasis on the practical effects of TPM and the diagnostic value of OEE across diverse industrial sectors. For example, (Adib *et al.*, 2022) reported OEE improvements ranging between

6.8% and 9.17% after applying TPM in the automotive manufacturing sector, demonstrating clear links between breakdown reduction and measurable gains in availability and performance. Likewise, (Cerdas-Navarro *et al.*, 2022) the importance of visibility tools and granular loss categorization in uncovering hidden capacity, showing that recurring speed losses and performance fluctuations often mask significant opportunities for improvement.

Recent investigations in wood-processing industries reveal similar patterns; a 2024 study on double-saw machines reported an OEE of 83.54 percent and identified minor stoppages and speed reduction as the most significant losses, suggesting a strong need for preventive maintenance in energy- and motion-intensive operations (Tatche and Mahmud, 2024). Research on metalworking SMEs further reinforces the positive impact of systematic TPM implementation. Lean-TPM integration in (Rojas *et al.*, 2024) Peruvian SMEs led to significant improvement, with OEE rising from 64.93 percent to 81.15 percent, demonstrating that even small-scale manufacturers can achieve substantial performance gains when loss identification is combined with operator training and cycle-time stabilization.

Parallel developments in the literature show growing interest in visual analytics and digital support tools for TPM deployment. (Hoseini-Nobari *et al.*, 2024) validated the usefulness of visual stream techniques in accelerating Six Big Losses identification, enabling quicker operator response to bottlenecks and process variations. (Mashud *et al.*, 2024) provided a comprehensive systematic review confirming that the TPM pillars, especially Autonomous Maintenance, Planned Maintenance, and Focused Improvement remain central to OEE enhancement and are consistently effective across multiple industries.

More recent studies emphasize the increasing role of data-driven and predictive TPM frameworks. (Abdallah *et al.*, 2025) proposed a sensor-supported TPM architecture that improved maintenance scheduling, responsiveness, and downtime reduction compared with traditional time-based maintenance systems. This reflects a broader shift toward digitalization, also evidenced in a 2025 study in the apparel manufacturing sector where Lean practices combined with real-time monitoring strengthened decision-making and sustained OEE gains (Choudhury *et al.*, 2025).

The plastics-processing industry also exhibits persistent limitations when TPM is underutilized. A 2025 investigation of injection-molding machines reported OEE values near 56 percent, with breakdowns and idling representing the most critical losses (JUSTME, 2025). This reinforces the importance of preventive maintenance and operator capability-building in precision-dependent environments. Further supporting evidence from a 2025 press-machine study confirms that TPM supported by Six Big Losses analysis enhances cycle stability and reduces performance variation, highlighting TPM's robustness as a method for improving productivity in metal-forming operations (UnknownAuthor, 2025).

Although these studies consistently confirm the effectiveness of OEE measurement and TPM application in various industrial contexts, the recent literature also reveals several notable gaps. Most empirical research focuses on single machines or isolated production cells, offering limited insight into complex, multi-stage manufacturing environments such as household appliance assembly, AC manufacturing, or electronics lines. Additionally, there is insufficient integration of Six Big Losses diagnostics with TPM pillars in a structured, stepwise manner, and relatively few studies offer real-world pre-post intervention results linking specific TPM actions to quantifiable OEE improvement. Furthermore, while literature shows increasing interest in digital and predictive TPM, their practical implementation remains limited in industries with strong inter-process dependencies or complex material flow.

These gaps highlight the need for research that combines comprehensive OEE evaluation, Six Big Losses diagnosis, and targeted TPM implementation within multi-stage production systems. Responding to these research gaps, the present study contributes a structured, data-driven analysis of OEE within a high-complexity production environment and applies TPM pillars tailored to the specific loss patterns of each process. Through the integration of Six Big Losses analysis, operator-centered maintenance practices, preventive maintenance scheduling, and focused improvement activities, this research demonstrates how TPM can be effectively applied beyond single-machine contexts. By offering quantifiable pre-post results and sector-specific insights, the study advances current understanding of TPM-driven performance improvement and provides an actionable framework for manufacturers seeking to enhance reliability and productivity in modern multi-process operations.

3. Methodology

This study adopts a structured, data-driven methodology to evaluate the Overall Equipment Effectiveness (OEE) of an air-conditioner manufacturing facility and to improve performance through targeted Total Productive Maintenance (TPM) initiatives. The methodological framework consists of five sequential phases: (i) data collection, (ii) OEE calculation, (iii) key issues identification based on OEE loss patterns, (iv) TPM implementation, and (v) post-implementation evaluation. The approach ensures systematic assessment of production efficiency and provides a practical path toward performance improvement.

3.1 Data Collection

Data was collected from five major processes of the AC manufacturing line: Blower & Fan Blade, Compressor Jacket, Evaporator & Condenser, Microchannel Condenser, and Powder Coating. For each process, information relevant to the three OEE components was gathered:

- Availability-related data: loading time, downtime, breakdown duration, setup/changeover time.
- Performance-related data: actual output, ideal cycle time, equipment speed, minor stoppages.
- Quality-related data: number of defects, rework quantity, and first-pass yield (Table 1).

Table 1. Process information

Process	Availability (%)	Performance (%)	Quality (%)	OEE (%)
Blower & Fan Blade	87.97%	97.68%	98.81%	84.90%
Compressor Jacket	68.71%	91.68%	100.00%	65.06%
Evaporator & Condenser	76.29%	99.83%	99.19%	75.32%
Microchannel Condenser	75.76%	90.44%	99.66%	67.30%
Powder Coating	67.30%	97.60%	99.93%	63.76%

The dataset provides a comprehensive representation of operational performance and forms the basis for calculating pre-TPM OEE values.

3.2 OEE Calculation

Overall Equipment Effectiveness (OEE) was computed using the standard model:

$$\text{OEE} = \text{Availability} \times \text{Performance} \times \text{Quality}$$

Where:

Availability reflects the impact of breakdowns and setup losses.

Performance represents cycle-time loss, speed reduction, and minor stoppages.

Quality captures defect and rework losses.

The calculated OEE values allowed benchmarking against the standard 85% threshold commonly used in manufacturing industries. Processes operating below this benchmark were selected for further investigation and improvement planning.

3.3 Six Big Losses Framework

The Six Big Losses framework helps manufacturers identify areas where productivity is lost and implement targeted countermeasures to address root causes. In TPM (Total Productive Maintenance), equipment failures are treated as indicators of systemic inefficiencies rather than isolated incidents, requiring organization-wide commitment for elimination.

1. Availability Loss (Downtime)

- Equipment Failure/Breakdowns: Unplanned downtime caused by failures of machines or tools.
- Setup and Adjustments/Changeovers: Planned downtime due to machine setup, changeovers, material shortages, or operator unavailability.

2. Performance Loss (Speed)

- Idling and Minor Stops: Short interruptions that do not require maintenance intervention but disrupt production rhythm.
- Reduced Speed/Slow Cycles: Equipment operating below its designed speed or exceeding target cycle times, reducing output capacity.

3. Quality Loss

- Process Defects and Rework: Scrap and rework caused by quality failures during steady-state production, leading to wasted machine time and resources.
- Reduced Yield/Startup Losses: Defective output during startup or stabilization due to inadequate preparation or unconditioned materials.

3.4 Key Issues Identification Based on OEE Loss Analysis

A full Root Cause Analysis (RCA) such as a fishbone diagram or 5-Why method was not conducted within the scope of this study. Instead, an OEE loss-driven diagnostic assessment was performed to identify key operational issues responsible for reduced effectiveness. This approach, based on loss patterns and the Six Big Losses framework, enabled the classification of issues without engaging in a complete RCA exercise (Table 2).

Table 2. OEE Loss Analysis

Process	OEE (%)	Key Issue
Compressor Jacket	65.06%	Low Availability (68.71%)
Evaporator & Condenser	75.32%	Low Availability (76.29%)
Microchannel Condenser	67.30%	Low Availability (75.76%) & Low Performance (90.44%)
Powder Coating	63.76%	Low Availability (67.30%)

Key issues were identified as follows:

1. Availability-Related Issues

Indicators of significant downtime and setup losses, such as:

- frequent unexpected stoppages,
- long changeover durations,
- irregular preventive maintenance activities,
- inconsistent machine readiness.

2. Performance-Related Issues

Symptoms of speed loss and minor stoppages, including:

- machines operating below ideal cycle time,
- intermittent jamming or misalignment,
- irregular cycle-time fluctuations across shifts.

3. Quality-Related Issues

Defect-prone operations contributing to quality loss, such as:

- brazing and leak-test inconsistencies,
- coating thickness variation or overspray,
- material surface contamination,
- unstable process parameters.

This structured loss-pattern assessment provided a clear understanding of which processes required targeted TPM interventions and what type of operational deficiencies were most critical.

3.5 TPM Implementation

Based on the identified key issues, a set of tailored TPM activities was deployed across the underperforming processes. The implementation focused on reducing availability, performance, and quality losses through the following pillars:

1. Autonomous Maintenance

- Training operators in basic inspection, cleaning, and lubrication
- Detecting minor abnormalities early
- Minimizing small stoppages

2. Planned Maintenance

- Scheduling maintenance activities to reduce unplanned breakdowns
- Introducing equipment-specific maintenance checklists
- Optimizing spare-part replacement intervals

3. Focused Improvement (Kaizen)

- Removing bottlenecks in brazing, leak testing, and coating
- Improving material flow, workstation layout, and cycle balance
- Establishing clear Standard Operating Procedures (SOPs)

4. Quality Maintenance

- Strengthening coating thickness control
- Enhancing brazing and leak-test reliability
- Calibrating inspection and measurement devices

These TPM initiatives were chosen based on the specific loss profile of each process to ensure maximum improvement impact.

3.6 Post-Implementation OEE Evaluation

Following TPM implementation, a second cycle of OEE measurement was conducted using the same methodology as the OEE Calculation. The post-TPM OEE results indicated measurable improvement across all processes. Notable gains include (Table 3):

Table 3. OEE Evaluation

Process	Pre-TPM OEE	Post-TPM OEE	Change%
Blower & Fan Blade	84.90%	86.50%	(+1.60%) (Improved)
Compressor Jacket	65.06%	71.20%	(+6.14%) (Improved)
Evaporator & Condenser	75.32%	77.50%	(+2.18%) (Improved)
Microchannel Condenser	67.30%	67.50%	(+0.20%) (Minimal Change)
Powder Coating	67.30%	63.76%	No Change

These improvements validate the effectiveness of the TPM interventions in reducing downtime, stabilizing performance, and improving product quality.

Here is a bar chart reflecting the improved OEE after TPM implementation in Figure 1-

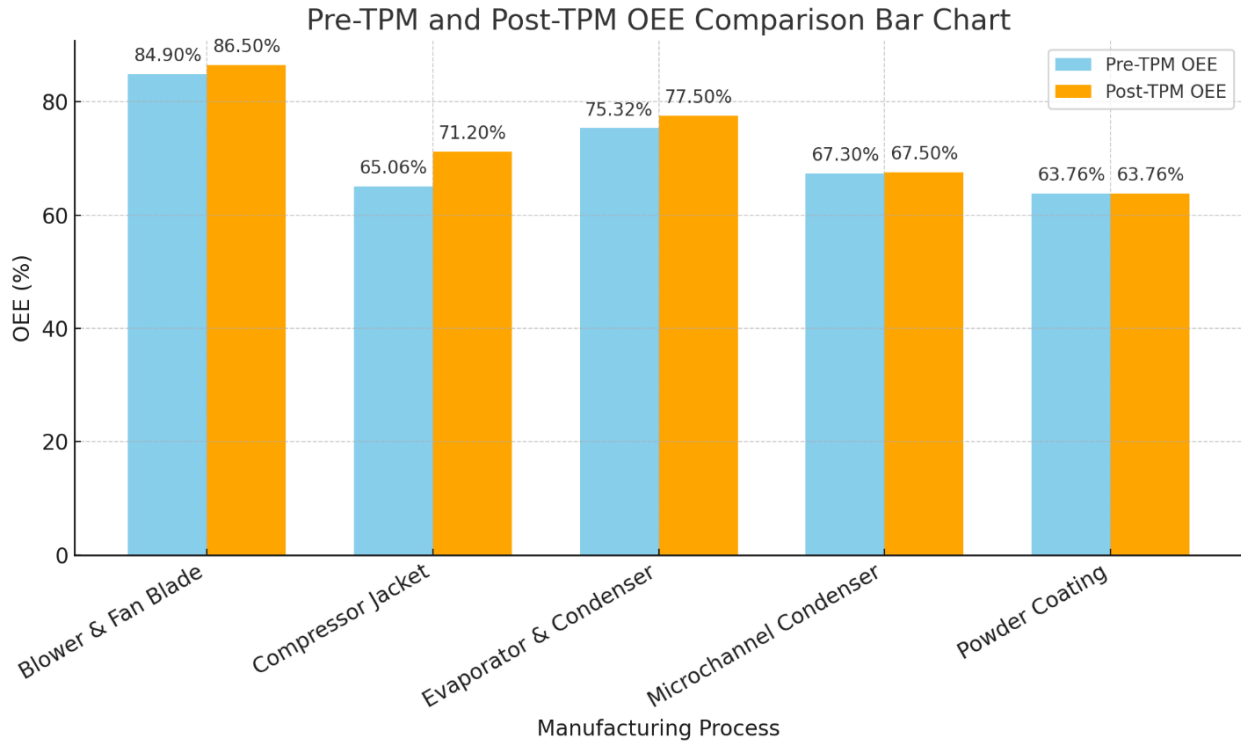


Figure 1. Comparison Bar-Chart.

4. Validation

4.1 Data Validation

Machine logs, production reports, and maintenance records were cross-checked to ensure accuracy. Shift-wise outputs were compared against automated system logs, and anomalies caused by sensor faults or manual entry errors were corrected before analysis.

4.2 OEE Validation

All OEE components Availability, Performance, and Quality were recalculated using data from independent sources (production logs, quality sheets, maintenance reports). Pre- and post-TPM values were compared to manually verified calculations to ensure consistency.

4.3 TPM Implementation Validation

Autonomous and Planned Maintenance activities were validated by checking operator training completion, maintenance logs, and breakdown history. Verified reduction in unplanned stoppages confirmed proper implementation of TPM actions.

4.4 Statistical Validation

Trend analysis was performed on pre- and post-TPM OEE values to verify sustainable improvement. Post-TPM OEE was benchmarked against the world-class standard (85%) as an additional validation measure.

6. Conclusion

This study examined the Overall Equipment Effectiveness of several key processes in an air-conditioner manufacturing line and evaluated how basic TPM activities can support improvement in production performance. The results showed that different types of losses such as reduced availability, speed variation, minor stoppages and quality defects were the main reasons behind low OEE in many stages of the line. Based on these findings, practical TPM actions are based on the actual conditions observed in each process. These activities helped stabilize machine operation and contributed to moderate OEE improvement in several areas, although some processes remained unchanged due to

their specific operational limitations. The overall outcome of this research indicates that applying TPM in a simple and practical manner can reduce common equipment losses and enhance the effectiveness of manufacturing operations when supported by continuous monitoring and accurate data collection. While the improvement varied among processes, the study provides a clear understanding of the current performance level of the line and creates a foundation for future development. More improvements can be achieved by extending the data collection period, strengthening loss analysis, and gradually integrating more structured maintenance practices and digital monitoring tools to support long-term productivity and reliability.

References

- Adib, A., Ahmed, T. and Sifat, S. A., Implementation of total productive maintenance (TPM) by evaluating overall equipment effectiveness (OEE): A case study, *Proceedings of the International Conference on Industrial Engineering and Operations Management (IEOM)*, Dhaka, Bangladesh, pp. 1–8, 2022.
- Abdallah, S., El Abbadi, L., Mitsou, J. and Belkadi, F., A data-driven framework for supporting the total productive maintenance strategy, *Expert Systems with Applications*, vol. 261, 123653, 2025.
- Cerdas-Navarro, M. E., Doost Mohammadi, N. and Thürer, M., Uncovering hidden capacity in overall equipment effectiveness, *International Journal of Production Economics*, vol. 248, 108426, 2022.
- Choudhury, A. K., Paul, R. K., Islam, M. T. and Islam, M. S., Achieving sustainable overall equipment effectiveness through digitalisation and lean practices in apparel manufacturing, *Engineering Reports*, vol. 7, no. 2, pp. 1–15, 2025.
- Hoseini-Nobari, A., Jooybari, M. B., Haghghat, A. A. and Yousif, M. F. M., Improving equipment effectiveness through visual stream, *International Journal of Systems Assurance Engineering and Management*, vol. 15, pp. 563–577, 2024.
- Mashud, M., Hasan, M. M., Sarkar, D. K. and Rahman, M., Total productive maintenance: An in-depth review with a systematic approach, *Journal of Quality in Maintenance Engineering*, vol. 30, no. 1, pp. 1–22, 2024.
- Rojas, J., Galvez, D., Lizaraburu, E. and Vega, C., Application of lean and TPM tools to improve overall equipment effectiveness: A case study of Peruvian metalworking SMEs, *Proceedings of the International Conference on Industrial Engineering and Operations Management (IEOM)*, Lima, Peru, pp. 421–430, 2024.
- Tatche, N. and Mahmud, H., Analysis of machine performance using overall equipment effectiveness and Six Big Losses: A double-saw machine case study, *Journal of Manufacturing Technology Management*, vol. 35, no. 4, pp. 612–628, 2024.
- Thürer, M., Stevenson, M. and Silva, C., Overall equipment effectiveness: A contemporary review of applications and limitations, *International Journal of Production Research*, vol. 61, no. 18, pp. 5864–5881, 2023.
- Yadav, A., Jain, R. and Mittal, M. L., Application of Six Big Losses framework to improve overall equipment effectiveness in injection moulding industries, *Journal of Manufacturing Processes*, vol. 86, pp. 480–492, 2023.
- Rahman, M. M., Islam, M. S. and Hossain, M. A., Improving press machine productivity through total productive maintenance and Six Big Losses analysis, *Journal of Industrial Engineering and Management Studies*, vol. 12, no. 1, pp. 33–48, 2025.

Biographies

Tanzil Ahamed is a current student of BGMEA University of Fashion and Technology (BUFT), Dhaka, Bangladesh, pursuing a Bachelor's degree in Industrial Engineering. He also serves as the Treasurer of the IEOM Student Chapter at BUFT and puts much effort into promoting research and innovation among his peers. His personal interests include ergonomics, machine learning, lean tools, and various aspects of manufacturing.

Md. Ariful Ferdous is a faculty member of the Department of Industrial Engineering at BGMEA University of Fashion and Technology (BUFT), Dhaka, Bangladesh. He completed his B.Sc. in Industrial and Production Engineering from Khulna University of Engineering and Technology (KUET) and earned his Master's degree in Applied Statistics and Data Science from Jahangirnagar University. His academic and professional interests include data-driven decision-making in production and manufacturing, with a focus on operations research, supply chain optimization, supply chain data analytics, machine learning, and lean manufacturing.

Rakibul Islam Rakib is an undergraduate student of the Department of Industrial Engineering at BGMEA University of Fashion and Technology (BUFT), Dhaka, Bangladesh. He is currently pursuing his B.Sc. degree in Industrial Engineering. His academic and research interests include defect analysis and defect reduction in manufacturing systems, with a focus on predictive modeling, probabilistic analysis, and data-driven quality improvement. He has

worked with production defect data to identify critical defect contributors and to develop analytical models for defect prediction and manufacturing performance improvement.

Seemanta Sarker Pranta is an undergraduate student of the Department of Industrial Engineering at BGMEA University of Fashion and Technology (BUFT), Dhaka, Bangladesh. He is currently pursuing his B.Sc. degree in Industrial Engineering. His academic interests include production planning and control, process optimization, and lean manufacturing applications. He is particularly interested in analyzing process flow, reducing non-value-added activities, and improving productivity through structured industrial engineering tools and performance measurement techniques.