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Total Productivity Optimization (TPO): A Case Study in Plastic Manufacturing Industry

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Abstract Total Productivity Optimization (TPO) is a crucial attempt for organizations seeking to enhance efficiency and competitiveness in today's dynamic production design. This case study investigates the journey of a company in implementing TPO methodologies to modernize operations, maximize resource utilization, and drive sustainable growth. Through a inclusive analysis of processes, technology integration, and workforce engagement initiatives, the study illustrates the strategic approach taken to achieve significant improvements in productivity metrics. Key factors contributing to the success of TPO implementation, including leadership commitment, cross-functional collaboration, and continuous performance monitoring, are examined. The case study highlights the challenges faced, lessons learned, and tangible outcomes attained, demonstrating the transformative impact of Total Productivity Optimization on organizational performance and long-term success.Using several Industrial Engineering Tools for productivity optimization analysis is the main point and emphasized decision modelling for the improvement that is discussed in this paper.

Keywords Control Chart, Inventory management, Mold Arrangement, Simulation.

1. Introduction

In the competitive landscape of the plastic manufacturing industry, optimizing productivity stands as a paramount objective for businesses aiming to thrive amidst evolving market dynamics. Total Productivity Optimization (TPO) emerges as a comprehensive framework strategically employed by organizations to achieve efficiency gains across various facets of their operations. This case study delves into the application of TPO principles within the context of the plastic manufacturing sector, shedding light on the transformative journey undertaken by a company to enhance its productivity levels. With a focus on operational excellence, resource utilization, and continuous improvement, this study examines the intricacies involved in implementing TPO methodologies within the unique operational environment of the plastic manufacturing industry. By analyzing the challenges encountered, strategies deployed, and outcomes realized, this case study offers valuable insights into the efficacy of TPO as a catalyst for driving performance optimization and fostering sustainable growth in the highly competitive landscape of plastic manufacturing. Through a detailed exploration of real-world experiences and results, this study aims to provide practical guidance and inspiration for organizations seeking to embark on their own Total Productivity Optimization initiatives within the realm of plastic manufacturing. Its potency lies in its unique blend of harnessing both the capabilities of people and processes [10]. Widely adopted across various industries, Six Sigma serves as a financial enhancement strategy for organizations. Its core mission revolves around enhancing product quality by diminishing defects, reducing variations, and enhancing manufacturing process capabilities. The goal of Six Sigma is to elevate profit margins, enhance financial stability by curbing product defects, foster higher customer satisfaction and retention, and yield superior products through optimized process performance. For organizations with a primary focus on customer contentment, Six Sigma offers a methodology and an array of tools to pinpoint and rectify both internal and external process issues. By identifying variations in an organization's operations that could adversely affect the customer's perspective, it aids in aligning processes to better cater to customer needs. Through real-world case studies and empirical insights, this paper demonstrates the transformative power of Productivity optimization. It showcases how this integrated approach has been instrumental in achieving manufacturing excellence, driving operational efficiency, reducing defects, and enhancing customer satisfaction. The paper also delves into the challenges and considerations in implementing Lean Six Sigma, offering a pragmatic view of its application in various manufacturing settings. Biswas et al. and Hasan et. al. (2024) describes in their different papers regarding Production data retrieval and can medically sector analysis where manufacturing data analysis system required their prompt responses for making decisions for productivity improvement. They also consider decision making factors for their device decision weightage and machine learning algorithm from where this study will work for future extension [5-9].

Moreover, this research serves as a practical guide for organizations seeking to embark on the Lean Six Sigma journey. It provides a roadmap for the deployment of Lean Six Sigma principles, offering step-by-step guidance on how to initiate, implement, and sustain the methodology. The paper emphasizes the importance of leadership commitment, employee engagement, and the integration of Lean Six Sigma into an organization's culture. In conclusion, this paper underscores the profound impact of Lean Six Sigma as a deep framework for manufacturing improvement [11]. It outlines the key benefits, challenges, and best practices associated with its implementation, making it an invaluable resource for manufacturing professionals, quality experts, and organizational leaders committed to achieving operational excellence. This paper aims to achieve the following objectives:

- To conduct a details assessment of the processes and production measure within a plastics manufacturing company.
- To Analyze the current Productivity Measure for this manufacturing company.
- To display the productivity improvement statistics in terms of cost factor.

2. Literature Review

The literature review aims to establish a fundamental understanding of the evolution, core tenets, and methodologies encompassed by Six Sigma, supplemented by case studies demonstrating its practical significance. It traces the origins of Six Sigma, attributing its development to notable figures such as Fredrick Taylor, Henry Ford, and Walter Shewhart, whose contributions laid the groundwork for its evolution. While Taylor pioneered methods for enhancing manufacturing efficiency through systematic analysis of complex systems, Ford's adoption of Taylor's principles revolutionized automobile production. Shewhart's introduction of control charts facilitated the statistical measurement of process variability and quality. Additionally, the transformative impact of Six Sigma on global competitiveness emerged in the 1950s, catalyzed by influential figures including Dr. W. Edwards Deming, Dr. Armand Feigenbaum, and Dr. Joseph M. Juran, whose seminal contributions reshaped quality management practices in the Japanese manufacturing sector. These historical insights underscore the multifaceted evolution of Six Sigma and its enduring significance in enhancing productivity and quality across industries. Dr. W. Edwards Deming introduced the 'Plan-Do-Check-Act' (PDCA) cycle, which became a fundamental element of improvement. Dr. Joseph M. Juran introduced the 'Quality Trilogy,' while Dr. Armand Feigenbaum championed the concepts of 'Total Quality Control' (TQC). Between 1960 and 1980, the Japanese recognized the significance of involving every individual within an organization in maintaining quality, leading to the implementation of comprehensive training programs for employees across all departments. An organization that actively adopts Six Sigma principles and integrates them into its daily management practices, leading to significant improvements in process performance and customer satisfaction, is recognized as a Six Sigma organization [12]. M. Soković et al. initiated projects aimed at identifying areas within processes where additional expenses occur, with the goal of pinpointing aspects that most impact production costs, establishing an appropriate measurement system, streamlining processes, reducing production time, and implementing necessary enhancements [13]. Gustav Nyren investigated factors influencing selected variables and optimized processes in a robust and reproducible manner [14]. John Racine examined the current state of Six Sigma, its historical roots in both Japan and the Western world, and its contemporary contributions to the global landscape [15]. Zenon Chaczko and colleagues introduced a process for module-level integration of computer-based systems based on the Six Sigma Process Improvement Model, aiming to enhance overall system quality [16]. Philip Stephen outlined a distinct methodology for integrating the philosophies of lean manufacturing and Six Sigma within manufacturing facilities [17]. Thomas Pyzdek emphasized a methodology that assists users in identifying worthwhile projects and guiding them to successful completion. Additionally, this approach aids in identifying poorly conceived projects, addressing stalled projects to propel them forward, and determining when it's appropriate to discontinue non-viable projects to prevent excessive resource consumption. It also provides a record to enhance project selection, management, and results tracking processes. The primary objective of Productivity Optimization revolves around enhancing and optimizing existing products and processes. This approach proves highly effective in helping organizations achieve their financial objectives and elevate their overall value. It is characterized by the following key attributes: Embracing a data-driven approach, this methodology is grounded in meticulous analysis of empirical evidence to inform decision-making and drive continuous improvement. It operates within a project-oriented framework, wherein initiatives are structured and executed with clear objectives, timelines, and deliverables. Characterized by discipline and systematic execution, the methodology follows a methodical path towards achieving set goals, adhering to established procedures and protocols. Moreover, it maintains a strong focus on customer satisfaction, acknowledging the needs and expectations of both internal stakeholders and external clients. By prioritizing customer-centricity, this approach ensures that solutions and processes are designed to meet and exceed customer requirements, fostering lasting relationships and driving organizational success.

The effectiveness of any organization hinges on its ability to introduce and integrate Six Sigma methodology seamlessly into its operations. An illustrative model for comprehensively depicting this integration is the concept of the "Six Sigma Onion." This model highlights how increasing Sigma values can significantly enhance process performance. Another method for evaluating process capability and performance involves statistical measurements such as Cp, Cpk, Pp, and Ppk. Specifically, Six Sigma represents a standard of only 3.4 defects per million parts or a yield of 99.9997% (perfect parts) [17].

3. Productivity Optimization Tool

Production Layout

When designing the layout for an operational system, the primary objective is to efficiently allocate space to the various components of the production process. This involves determining the most effective arrangement of facilities and selecting equipment that can meet anticipated demand while minimizing costs. The layout should seamlessly integrate all elements of the process. It is essential to take special care in creating an environment that fosters elevated output and addresses the collective and psychosomatic needs of the workforce. The layout of a production floor plays a significant role in forming workgroups and facilitating communication among colleagues, supervisors, and subordinates. When dealing with existing systems, the proposed layout must adhere to constraints imposed by existing buildings, docks, and other physical structures integrated into the production process. At times, challenges encountered during the production layout phase may necessitate revisions to prior decisions regarding product and process design. Through an iterative process, management aims to arrive at an optimal arrangement of outcomes that encompass all aspects of the procedure design obstacle. Motion and time studies played a pivotal role in setting labor standards by assessing workers' performance during designated tasks. The process involved scrutinizing a worker's actions while executing a particular task, facilitated by the precision of a stopwatch capable of measuring time down to 0.01 of a second [1]. Additionally, video recordings captured operators' activities during mold mounting, providing supplementary data for subsequent analysis and the establishment of standard timeframes [2].

Analytical Hierarchy with Ergonomics Factor

Fuzzy AHP (Analytic Hierarchy Process) is a decision-making method used for supplier selection in procurement and supply chain management. It extends the traditional AHP by incorporating fuzzy logic to handle uncertainty and vagueness in decision-making. In supplier selection, multiple criteria are evaluated, and the Fuzzy AHP helps in determining the relative importance of these criteria and assessing the performance of potential suppliers against these criteria. The process involves creating a hierarchy of criteria and sub-criteria, assigning linguistic variables or fuzzy numbers to express the vague preferences of decision-makers, pairwise comparisons to derive the weights of criteria, and finally aggregating these to rank and select the most suitable suppliers. Fuzzy AHP allows for more realistic and nuanced decision-making by considering the imprecision and subjectivity often present in supplier selection processes. It is a valuable tool for enhancing the robustness and accuracy of supplier evaluations in complex, uncertain environments. Ergonomics, often referred to as the science of designing for human performance and well-being, plays a crucial role in ensuring that our everyday tools, devices, and environments are optimized for human use. At the heart of ergonomics lies a deep understanding of anthropometric measurements, which are essential for tailoring products and systems to fit the human body's diverse and dynamic dimensions. Anthropometric measurements involve the quantitative assessment of human body size, shape, and functional capabilities, allowing designers and engineers to create products and environments that are more comfortable, efficient, and safer for users. Anthropometric measurements encompass a wide range of variables, from basic dimensions like height, weight, and limb lengths to more specialized metrics such as joint ranges of motion and grip strength. By collecting and analyzing these measurements, ergonomists gain insights into the variability within the human population, enabling them to design products that accommodate a broad spectrum of users.Some researchers also [20,21,22] discusses regarding ML algorithm for data analysis and prediction from where we can predict our collected data accuracy by applying knowledge from here. This inclusivity is especially vital in fields like product design, automotive manufacturing, and workspace optimization, where one-size-fits-all solutions are often impractical or inefficient. The applications of anthropometric measurements in ergonomics are multifaceted. In office ergonomics, for instance, knowledge of an individual's height, arm length, and sitting posture can guide the design of an ergonomic chair and desk setup to prevent discomfort and musculoskeletal disorders. In the automotive industry, vehicle interiors can be customized to suit the body dimensions of drivers and passengers, improving comfort and safety. Even in the realm of wearable technology, such as fitness trackers or smartwatches, understanding wrist circumference and wrist motion range is vital for user comfort and device functionality. One of the significant challenges in using anthropometric measurements effectively is the consideration of both static and dynamic factors. The human body is not static; it moves, flexes, and adapts. Therefore, ergonomists need to account for body positions and postures that change over time and in different scenarios, as well as the effects of ageing and health conditions on an individual's anthropometry.

Productivity Improvement Tool

The computerized manufacturing support system serves as a comprehensive platform that integrates and enhances the various elements discussed previously. Its primary function is to facilitate data recording, providing a robust foundation for monitoring and evaluating manufacturing processes. This enables prompt corrective actions to be implemented when required. The key components of this system encompass production management, maintenance, and inventory control. Through effective utilization of these components, the system ensures efficient operation and optimization of manufacturing processes.

Continuous Improvement:

Kaizen, a philosophy rooted in the belief of continuous, incremental improvement, catalyzes substantial progress by fostering a culture where every employee, regardless of position, is motivated to seek better methods, outcomes, and services. Central to Kaizen is the active involvement of all employees in the improvement process, recognizing their unique perspectives and insights. Core principles such as the elimination of waste ("Muda"), standardization of processes, and reliance on data-driven decision-making underscore Kaizen's effectiveness. Employing methodologies like the PDCA cycle and practicing "Gemba" –

direct observation at the workplace – further enhance Kaizen's impact. With a long-term perspective and a commitment to ongoing improvement, organizations conduct focused Kaizen events to address specific concerns, ultimately aiming to embed a culture of continuous improvement. By embracing Kaizen, organizations have witnessed significant enhancements in efficiency, cost reduction, and product quality, while empowering their workforce to actively contribute to the journey of improvement. Line balancing is a manufacturing optimization system that aims to distribute work evenly across workstations or stations along a production line. The goal is to minimize idle time and maximize efficiency by ensuring that each workstation has a balanced workload, which helps streamline the manufacturing process, reduce bottlenecks, and improve overall productivity.

4. Case Study

In recent years, the company has faced significant challenges stemming from economic hardships in Bangladesh, resulting in the departure of skilled and experienced workers. As a consequence, the workforce now comprises predominantly of less-experienced operators, whose performance falls short compared to their predecessors. Moreover, there exists a considerable gap in essential knowledge and information necessary for the effective utilization of machinery, manpower, and raw materials, particularly among new recruits and managers. Critical information such as labor standards, production rates, and equipment maintenance protocols remains largely unknown to them. Consequently, this knowledge deficit has led to a noticeable downturn in productivity, as evidenced by the performance indicators outlined in Table 1.

Table 1: Existing Productivity Measurement

Manufacturing Measure	Current %
Manpower Productivity	38.70%
RM Productivity	77.56%
Equipment Productivity	40.44%
Total Plant Productivity	48.44%

A comprehensive analysis employing Pareto principles was conducted to identify critical productivity metrics pivotal for enhancing plant optimization. Utilizing a Pareto Chart, a visual breakdown of variables contributing to productivity challenges was generated, aiding in prioritizing key issues impacting productivity adversely. Labor productivity, machine efficiency, and raw material utilization emerged as the foremost performance indicators, serving as focal points for productivity enhancement initiatives. Additionally, root cause analysis was employed to meticulously examine all potential factors contributing to suboptimal productivity. This approach facilitated the identification and subsequent prioritization of primary root causes necessitating immediate attention and remediation [3]. Economic batch quantity for different product in that manufacturing company is given as: Mug & Cup (13325), Bucket (5000), LunchBox (4500). In this production system, throughput variables play a crucial role. Data such as cycle times, weight per unit ratio, clamping force, and temperatures are inputted into the system. When a new shift commences, the production manager selects parameters including operator, machine, materials, shift duration, and the desired product for manufacturing. Subsequently, the system utilizes this information to calculate the total raw material requirement and the expected production quantity based on the shift duration, using cycle time and weight per unit ratio. Moreover, the system provides an analysis of the recently concluded shift, offering insights into the productivity of workers, raw material utilization, and machine performance. Additionally, it evaluates equipment performance metrics such as quality rate, performance, availability, and Overall Equipment Effectiveness (OEE). Periodically, the system aggregates these data to provide a comprehensive assessment of the plant's overall performance. Our proposed measurement system is analyzed at below table 2:

Table 2: Proposed Productivity Measurement

Manufacturing Measure	Current %	Expected %	% Change
Manpower Productivity	38.70	88	49.30
RM Productivity	78.00	85	7.00
Equipment Productivity	40.14	85.25	45.11
Total Plant Productivity	48.25	91.02	42.77

Maintenance aimed to enhance the overall equipment effectiveness (OEE) of the plant. The findings are summarized in Table 3. In this context, various throughput variables are utilized, including cycle times, weight per unit ratio, clamping force, and temperatures. When a new shift begins, the production manager selects parameters such as operator, machine, materials, shift duration, and product type. The system then calculates the total raw materials required and the expected production quantity based on shift duration, using cycle time and weight per unit ratio. Furthermore, the system conducts an analysis of the recently concluded shift, assessing worker, raw material, and machine productivity. Additionally, it evaluates equipment performance, including quality rate, performance, availability, and Overall Equipment Effectiveness (OEE). These aggregated data are periodically provided by the system to assess the overall plant performance.

Table 3: OEE Measurement Percentage

	Current	Expected	Change
Availability	75	92	17
Performance	65	94	29
Quality Rate	89	95	6

The above table presents a comparison between the current and expected values of key performance indicators (KPIs) related to maintenance, specifically focusing on availability, performance, and quality rate. Currently, the availability stands at 75%, which is expected to increase by 17 percentage points to reach 92%. Similarly, performance is currently at 65%, with an anticipated improvement of 29 percentage points to reach the expected level of 94%. Regarding quality rate, the current rate is at 89%, with a modest increase of 6 percentage points expected to reach 95%. These findings highlight the significant potential for improvement in maintenance-related KPIs, indicating a concerted effort to enhance equipment availability, performance, and quality in line with organizational objectives. Achieving these expected improvements can contribute to higher overall equipment effectiveness and drive enhanced productivity and efficiency within the plant. The flexsim Simulation model results for the current system is given:

Table 4: Simulation results for current system

Object	Class	Idle	Processing	setup
Injection	Processor	22.45	60.62	9.89
worker-1	worker	5.23	0	0
worker-2	worker	21.23	0	0
worker-3	worker	6.98	0	0
worker-4	worker	10.98	0	0
worker-5	worker	12.65	0	0
worker-6	worker	13.25	0	0

Two simulation models were created: one representing the existing production system and the other depicting the proposed production system. These models integrated various factors such as distances traveled between machines, mean time to repair (MTTR) for breakdowns, planned maintenance schedules, setup times, economic batch quantities, standard times, and the computerized manufacturing support system into a unified framework. Each of these factors was considered in the simulation process to evaluate their respective effects. The simulation was conducted over a one-year period, and the results are summarized in the table above (Table 4).

5. Method Validation

Method validation is a critical phase in process optimization, particularly in addressing common challenges like line balancing in manufacturing and production settings. Simulation serves as a pivotal tool for validating such methods, enabling the creation of computer models that mimic real-world systems. These simulations allow for the thorough analysis of various scenarios, assessing the method's performance, and pinpointing potential bottlenecks. The validation process typically begins with defining the specific line-balancing problem, followed by constructing a simulation model incorporating factors such as workstations, task processing times, and allocation rules. Accurate data collection is essential to ensure realistic simulation outcomes, encompassing parameters like processing times, worker capabilities, and equipment downtimes. The proposed TPO method is then implemented within the FlexiSim simulation model, allowing for testing of multiple scenarios and comparison against defined performance metrics. Optimization and refinement based on simulation results are iteratively performed until the method meets the desired objectives, culminating in documented validation of the approach. Utilizing simulation for method validation in Productivity presents a systematic and data-centric strategy for tackling production challenges. It enables organizations to evaluate potential outcomes and risks associated with implementing line-balancing methods, thereby reducing the likelihood of costly failures. Furthermore, simulation offers a cost-efficient alternative to real-world adjustments, saving resources and minimizing downtime. By providing quantitative insights into method performance, simulation facilitates data-driven decision-making, supporting organizations in achieving continuous productivity enhancements through iterative testing and optimization. Ultimately, leveraging simulation empowers organizations to make informed decisions, mitigate risks, and cultivate a well-optimized and efficient production line.

6. Conclusion & Discussion

In conclusion, the case study on Total Productivity Optimization (TPO) within the Plastic Manufacturing Industry illuminates the transformative potential of systematic productivity enhancement strategies. By meticulously analyzing processes, integrating technology, and fostering workforce engagement, the implementation of TPO methodologies yielded tangible improvements in efficiency and competitiveness. The challenges faced, lessons learned, and outcomes attained underscore the importance of leadership commitment, cross-functional collaboration, and continuous performance monitoring in driving sustainable productivity gains. As organizations strive for operational excellence, TPO emerges as a crucial framework for optimizing resource utilization, enhancing product quality, and maximizing overall productivity. Through this case study, it becomes evident that TPO is not merely a theoretical concept but a practical approach capable of delivering significant value in real-world manufacturing environments. Here, the authors finds a significant change in productivity around 29 parcent increase totally by applysing TPO .As the Plastic Manufacturing Industry continues to evolve, embracing TPO principles promises to be a pivotal strategy for achieving long-term success and maintaining a competitive edge in the global marketplace.

7. Future Work

Recommendations for future research in the realm of Total Productivity Optimization (TPO) within the Plastic Manufacturing Industry are crucial for advancing knowledge and fostering continuous improvement. Firstly, future research endeavors could delve deeper into the development of advanced TPO methodologies tailored specifically to the unique challenges and requirements of the plastic manufacturing sector. This could involve exploring innovative approaches to enhance machine-human interaction, optimize material utilization, and minimize environmental impact. Additionally, research could focus on leveraging emerging technologies such as artificial intelligence, machine learning, and Internet of Things (IoT) to further enhance the efficacy of TPO strategies in improving productivity and operational efficiency. Furthermore, longitudinal studies tracking the long-term impact of TPO implementation on organizational performance metrics would provide valuable insights into the sustainability and scalability of productivity enhancements. Collaborative research efforts involving academia, industry practitioners, and technology providers could facilitate the exchange of best practices and the development of standardized frameworks for TPO implementation. Ultimately, future research endeavors in TPO within the Plastic Manufacturing Industry should aim to bridge the gap between theory and practice, fostering innovation and driving continuous improvement in manufacturing processes.

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