Productivity Optimization Techniques Using Industrial Engineering Tools

Mahboob Al Bashar[1], Md Abu Taher[2], Dilara Ashrafi[3]

[1]*Cullen College of Engineering, Industrial Engineering, University of Houston, Houston, Texas, US*
https://orcid.org/0009-0009-0804-1863
[2]*Cullen College of Engineering, Industrial Engineering, University of Houston, Houston, Texas, US*
https://orcid.org/0009-0000-7459-7530
[3]*Department of Applied Science, Universiti Teknologi MARA, Malaysia*
https://orcid.org/0009-0000-6768-4724

ABSTRACT

This article investigates the use of industrial engineering tools and techniques to improve productivity across a variety of industries. These techniques greatly increase operational performance by systematically eliminating inefficiencies and streamlining operations. Time and Motion Studies, Lean Manufacturing, and Six Sigma are three key methodologies presented for process analysis, waste reduction, and defect mitigation. Ergonomics and Just-In-Time (JIT) Production are highlighted for their contributions to employee well-being and inventory cost savings. Total Quality Management (TQM) and Workload Balancing guarantee that quality is embedded throughout the process and that work is distributed fairly. Supply Chain Optimization and Simulation Modeling are evaluated for their ability to improve logistics and process analysis. The effectiveness of project management techniques such as Gantt Charts, Critical Path Method (CPM), and Program Evaluation and Review Technique (PERT) in project planning and execution is described in detail. Benchmarking allows for a comparison approach to implementing industry best practices, whereas automation and robotics demonstrate the efficiency improvements from technology adoption. Finally, Data Analytics and Big Data are examined in terms of its predictive and analytical powers, which allow for more informed decision making. Collectively, these technologies create a solid foundation for attaining significant productivity gains. The combination of these strategies results in streamlined processes, less waste, higher quality, and greater adaptability in the face of changing industry needs. This extensive examination emphasizes the importance of industrial engineering in increasing productivity and operational excellence.

Keyword: *Industrial Engineering, Productivity Optimization, Lean Manufacturing, Six Sigma, Ergonomics, Just-In-Time Production, Total Quality Management, Supply Chain Optimization, Simulation Modeling, Automation, Data Analytics.*

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1. Introduction

In today's competitive world, optimizing productivity is a vital goal for firms across several sectors. The application of industrial engineering tools and processes is critical in reaching this goal. These methodologies offer systematic approaches to examining and improving processes, resulting in more efficiency, less waste, and higher quality. As firms attempt to preserve a competitive advantage, knowing and executing these approaches is critical to operational excellence.

The Time and Motion Study is a fundamental technique in industrial engineering that involves comprehensive observation and analysis of labor operations. Organizations can identify inefficiencies and simplify workflows by recording the time it takes to complete each job and the movements involved. This strategy not only aids in task scheduling but also helps to enhance ergonomics, reduce worker tiredness, and increase productivity.

Another essential methodology is Lean Manufacturing, which aims to reduce waste while maintaining production. Techniques like 5S, Value Stream Mapping (VSM), and Kaizen are essential components of Lean, encouraging a culture of constant improvement and efficiency. Similarly, Six Sigma's structured DMAIC (Define, Measure, Analyze, Improve, Control) strategy aims to reduce defects and process variability. These techniques combined lead to considerable improvements in process quality and operational efficiency.

The 5S concept in industrial engineering serves as a foundation for improving workplace efficiency and safety. It starts with "Sort," which identifies and removes unneeded things, decluttering the workspace for maximum functionality. "Set in Order" follows, which organizes critical tools and materials in a methodical manner for quick access and workflow efficiency. This precise layout saves time hunting for products and increases efficiency. As a result, "Shine" stresses cleanliness and maintenance, extending equipment life and preventing safety issues. "Standardize" develops uniform methods and techniques, which promotes uniformity throughout operations. Finally, "Sustain" enforces continuous improvement through discipline and regular audits, instilling the 5S principles in the company culture for long-term success.

The 5S technique promotes efficiency, safety, and excellence in industrial settings. Its methodical approach improves workplaces by establishing order, cleanliness, and consistency. Organizations that integrate 5S principles into their daily operations not only increase productivity but also improve employee morale and well-being. The consistent use of 5S principles promotes a culture of continuous improvement, ensuring that efficiency gains are preserved and expanded over time. Through 5S, industrial engineering achieves not just operational excellence but also lays the groundwork for a safer and more satisfying workplace.

Value Stream Mapping (VSM) is a sophisticated method in industrial engineering that analyzes and visualizes the flow of materials and information needed to deliver a product or service to customers. It provides a thorough overview of the whole manufacturing process, from raw material acquisition to finished goods delivery, allowing firms to detect inefficiencies, bottlenecks, and opportunities for improvement. VSM entails mapping the current status of the value stream, which includes all process steps, cycle times, inventories, and information flows. This visualization enables stakeholders to acquire a thorough grasp of how value is created and where waste occurs in the system.

Once the present state has been mapped, the next step is to create a future state map that depicts the ideal state of the value stream, including changes to remove waste, shorten lead times, and increase overall efficiency. Organizations can discover areas for improvement and build practical strategies to attain their objectives by comparing the current and future states. VSM is a significant tool for continuous improvement, allowing firms to streamline operations, maximize resources, and provide more value to consumers.

Kaizen, derived from the Japanese words "kai" (change) and "zen" (good), represents the philosophy of constant development. In industrial engineering, Kaizen is the concept of making tiny, incremental improvements to processes, systems, and workflows to improve efficiency, quality, and productivity over time. It promotes a culture of continuous improvement in which all employees, from top management to frontline workers, are encouraged to discover and implement possibilities for improvement collectively. Kaizen is not about abrupt changes, but rather about instilling a culture of continuous progress and refinement.

At its foundation, Kaizen promotes the value of employee participation and empowerment. Frontline workers, who are closest to the processes and frequently have useful insights, are encouraged to share suggestions for improvement. This participative method not only produces more innovative ideas, but it also builds employee ownership and participation. Kaizen also encourages a blame-free culture in which mistakes are considered as opportunities for learning and progress rather than failures. Organizations can achieve continuous improvement by fostering a supportive environment that encourages experimentation and innovation.

Kaizen's influence goes beyond operational gains; it also improves company culture and employee morale. Organizations can demonstrate their commitment to employee growth and well-being by recognizing and rewarding contributions to continuous improvement. This, in turn, promotes a pleasant work atmosphere in which people feel respected, inspired, and empowered to put forth their best efforts. Finally, Kaizen enables firms to adapt to changing market conditions, remain competitive, and achieve long-term growth by constantly refining their processes and providing more value to consumers.

Ergonomics and Just-In-Time (JIT) Production help to improve productivity even further. Ergonomics guarantees that workplace design is compatible with human capabilities, reducing injuries and increasing productivity. JIT manufacturing, on the other hand, focuses on lowering inventory costs and lead times by producing only what is required at the time of demand. These tactics not only increase production, but also boost worker satisfaction and save operating expenses.

Just-In-Time (JIT) production is a lean manufacturing method that aims to reduce waste while increasing efficiency by creating only what is needed, when it is needed, and in the exact quantity necessary. JIT, which evolved from the Toyota Production System, transformed manufacturing by stressing the reduction of surplus inventory, shorter lead times, and more production flexibility. JIT assists firms in lowering storage costs, reducing overproduction, and responding more swiftly to changes in market demand by synchronizing production with customer demand.

JIT is built around the principle of pull-based production, which begins production in response to actual customer demand rather than predicted demand. This technique enables businesses to avoid accumulating extra inventory, which can tie up cash, increase storage expenses, and lead to obsolescence. JIT also encourages continual improvement throughout the manufacturing process, with an emphasis on shorter setup times, higher quality, and more efficient workflows. Organizations that embrace JIT concepts can achieve higher levels of efficiency, quality, and responsiveness, resulting in increased value to consumers while reducing waste and expenses.

Total Quality Management (TQM) is a holistic management style that emphasizes continuous improvement, customer focus, and employee involvement in the pursuit of organizational excellence. TQM arose from quality management principles developed in Japan following World War II, and it gained significant appeal in the late twentieth century as firms understood the importance of quality in attaining a competitive advantage. At its foundation, TQM seeks to incorporate quality standards into all elements of an organization's operations, from product design and manufacturing to customer support and service.

One of the fundamental principles of TQM is the emphasis on meeting or surpassing customer expectations. Understanding consumer demands and preferences allows firms to create products and services that provide value and satisfaction. TQM emphasizes the value of listening to customer feedback, collecting statistics on customer satisfaction, and constantly improving products and processes to better satisfy consumer needs. Organizations that adopt this customer-centric approach can develop strong customer relationships, increase brand loyalty, and gain a competitive advantage in the marketplace.

Another key component of TQM is the participation of all employees in the pursuit of quality. TQM understands that quality is everyone's responsibility, from top management to front-line employees. Organizations can leverage their workforce's aggregate knowledge and skills by allowing employees to identify problems, propose solutions, and engage in improvement projects. TQM also fosters a culture of collaboration and teamwork, encouraging staff to cooperate across departments and functions to achieve common quality objectives. Organizations can build a culture of continuous improvement, innovation, and quality that supports long-term success by including employees and working together.

DMAIC, which stands for Define, Measure, Analyze, Improve, and Control, is a structured problem-solving methodology used in industrial manufacturing to improve processes, eliminate errors, and increase overall efficiency and quality. DMAIC, based on the Six Sigma methodology, offers a systematic approach to detecting and fixing process variances and faults in order to produce quantitative and long-term improvements. DMAIC's phases are meticulously developed to assist teams through the problem-solving and continuous improvement process.

The first step, Define, entails precisely describing the problem or potential for improvement, as well as the project goals and objectives. This phase establishes the groundwork for the remainder of the DMAIC process by ensuring that everyone engaged has a shared knowledge of the problem and its relevance. Next, during the Measure phase, teams collect data and metrics to characterize the current status of the process and set a performance baseline. This includes defining important process parameters, gathering data, and analyzing process performance to determine the scope of the issue and its influence on operations.

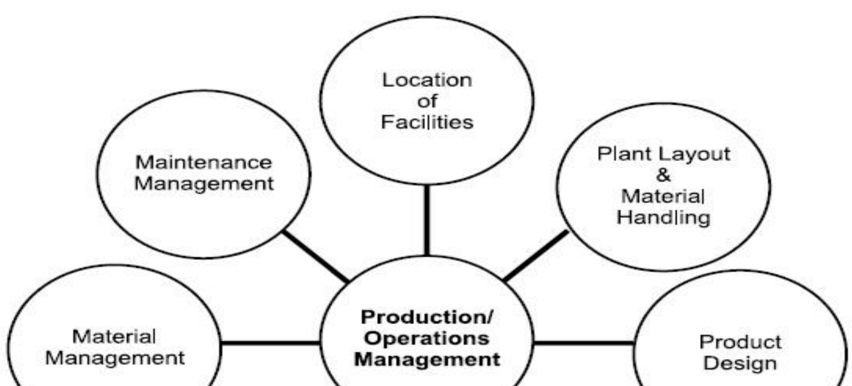
Following the Measure phase, the Analyze phase focuses on determining the underlying reasons of the problem or variance in the process. Teams employ statistical tools and techniques to evaluate data, detect patterns, and discover underlying causes of the problem. This phase allows teams to obtain a deeper understanding of the process and evaluate improvement options based on their impact and feasibility. Once underlying causes have been discovered, the increase phase focuses on applying solutions and modifying the process to address the root causes and increase performance. Finally, in the Control phase, teams build monitoring methods and procedures to maintain the progress made and prevent problems from recurring. Industrial producers can use the DMAIC technique to systematically discover, analyze, and address process issues, resulting in significant and sustained gains in quality, efficiency, and customer satisfaction.

Aside from these strategies, sophisticated methodologies like as Total Quality Management (TQM), Supply Chain Optimization, and Simulation Modeling offer comprehensive frameworks for continuous improvement. TQM emphasizes quality at all organizational levels, whereas supply chain optimization improves the efficiency of material and information flows. Simulation modeling enables firms to test and refine processes in a virtual environment prior to their real-world implementation. Together, these tools and strategies provide a solid platform for attaining long-term productivity gains and operational excellence.

2. Literature Review

The pursuit of productivity optimization using industrial engineering techniques has been intensively researched, with a wide range of methodologies leading to major advances across multiple industries. Frederick Taylor and Frank and Lillian Gilbreth pioneered Time and Motion Studies in the early twentieth century, laying the framework for current process optimization. Recent research, such as that conducted by Heizer and Render (2016), shows that extensive analysis of tasks and worker motions can discover inefficiencies and recommend modifications, resulting in significant productivity and ergonomic gains.

Lean Manufacturing originated with the Toyota Production System, and Womack, Jones, and Roos (1990) popularized its principles in their seminal article "The Machine That Changed the World." Subsequent studies, such as Liker's "The Toyota Way" (2004), demonstrates the efficacy of Lean approaches like 5S, Value Stream Mapping (VSM), and continuous improvement (Kaizen) in reducing waste and increasing operating efficiency. Empirical studies, such as those conducted by Shah and Ward (2007), show that firms that follow Lean concepts achieve improved performance indicators, such as shorter cycle times and higher throughput.



Motorola introduced the Six Sigma approach in the 1980s, which was further improved by General Electric in the 1990s. Its DMAIC framework focuses on defect reduction and process variability minimization. Linderman et al. (2003) and Pande, Neuman, and Cavanagh (2000) found that Six Sigma improves quality and operational performance. Case studies from many industries show that Six Sigma projects frequently result in significant cost reductions and quality improvements, highlighting its worth as a productivity enhancement technique.

Ergonomics and Just-In-Time (JIT) Production are other important areas of study. Dul and Weerdmeester (2008) define ergonomics as the process of developing work environments to meet workers' capacities, hence reducing injury rates and increasing productivity. Karwowski and Marras (2003) found that ergonomic interventions are critical for preserving worker health and productivity. JIT manufacturing, based on Toyota's techniques and described in Monden's "Toyota Production System" (2011), emphasizes the benefits of reducing inventory and producing goods in response to demand. Schonberger (1982) and others found that JIT deployment reduces lead times and inventory costs.

Finally, complete frameworks like Total Quality Management (TQM), Supply Chain Optimization, and Simulation Modeling have been thoroughly documented. TQM, as discussed by Deming (1986) and Juran (1988), aims to embed quality at all levels of a company. Flynn, Schroeder, and Sakakibara (1995) found that TQM techniques led to improved operational performance. Simchi-Levi et al. (2003) investigated Supply Chain Optimization, which focuses on the integration and simplification of supply chain activities to improve efficiency and responsiveness. Banks et al. (2001) found that simulation modeling provides effective tools for testing and refining processes in a virtual environment, allowing for more informed decision-making and risk reduction. Collectively, these collections of literature provide a solid foundation for understanding and implementing industrial engineering approaches to improve productivity in a variety of settings.

3. Theoretical Framework

The theoretical basis for this research is based on industrial engineering concepts and processes, which include a wide range of tools and strategies for increasing productivity. This framework combines a variety of known ideas and models to form a unified approach to studying and improving industrial processes. This framework's core components include time and motion studies, lean manufacturing, six sigma, ergonomics, just-in-time (JIT) production, total quality management (TQM), supply chain optimization, and simulation modeling.

The concepts of scientific management created by Frederick Taylor, as well as Frank and Lillian Gilbreth's motion studies, serve as the foundation for this theoretical framework. These studies take a methodical approach to breaking down work processes into individual tasks and movements, allowing for extensive examination and optimization. The basic premise holds that by removing needless motions and standardizing efficient processes, productivity may be considerably increased.

Lean Manufacturing is based on Toyota's Production System, which emphasizes waste removal (muda) and continual improvement (kaizen). The theoretical foundation of Lean Manufacturing includes the identification and elimination of non-value-added processes. This strategy incorporates key principles such as 5S (sort, set in order, shine, standardize, and sustain), Value Stream Mapping (VSM), and Just-In-Time (JIT) production. These notions are based on the theory that decreasing waste and enhancing flow leads to increased productivity and efficiency.

Six Sigma is a data-driven methodology designed to eliminate flaws and unpredictability in processes. Six Sigma is theoretically based on statistical quality control and process improvement approaches. The DMAIC (Define, Measure, Analyze, Improve, Control) framework is important to Six Sigma, as it provides a disciplined approach to issue solving and process optimization. The theory holds that by meticulously evaluating process data and systematically eliminating causes of variability, companies can attain near-perfect quality standards.

Ergonomics is founded on the idea that creating work settings to accommodate human capacities can increase productivity while lowering the risk of damage. This technique combines insights from human factors engineering and biomechanics to design workspaces that promote peak performance. The ergonomic hypothesis states that well-designed tools, equipment, and workspaces can reduce physical strain and tiredness, resulting in enhanced efficiency and worker satisfaction.

JIT manufacturing is a methodology that closely matches with Lean Manufacturing principles, emphasizing creating only what is needed, when it is required. JIT's theoretical underpinning is based on reducing inventory levels and lead times, which reduces waste and improves demand responsiveness. This method is founded on the premise that by synchronizing output with demand, companies can improve their efficiency and flexibility.

TQM is based on the premise that quality should be integrated into all elements of an organization's operations. Pioneers such as Deming, Juran, and Crosby helped shape TQM principles, which emphasize continuous improvement, customer focus, and staff involvement. TQM's theoretical framework proposes that a comprehensive approach to quality management can lead to increased performance and competitive advantage.

Supply Chain Optimization is the integration and coordination of all activities involved in the manufacture and delivery of commodities. The theoretical foundation for supply chain optimization is based on operations research and systems theory, both of which emphasize the necessity of considering the supply chain as a network. Organizations can improve their efficiency and responsiveness by improving each component and its relationships.

Simulation modeling provides a theoretical foundation for analyzing complex systems and processes via virtual experiments. This method is based on systems theory and computer modeling approaches, allowing firms to test and develop processes in a risk-free setting. According to the hypothesis, utilizing simulation to forecast the results of numerous situations allows firms to make more informed decisions and optimize their operations.

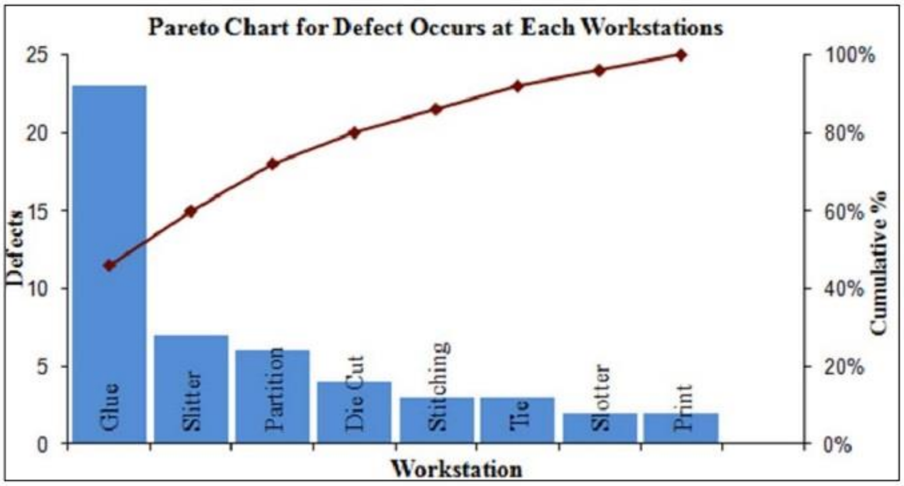
The combination of these theoretical components results in a comprehensive framework for productivity optimization. Each component covers a distinct facet of industrial operations, ranging from detailed job analysis to overall quality management and supply chain coordination. Organizations can use the capabilities of these approaches to systematically uncover inefficiencies, implement improvements, and achieve long-term productivity benefits. This theoretical framework establishes a solid foundation for the practical use of industrial engineering tools and procedures in a variety of industrial settings.

4. Methodology

Several case studies from various industries are chosen to present a diverse viewpoint on the use of industrial engineering technologies. The selection criteria include industry type, firm size, and operational complexity. To ensure that the conclusions are generalizable, case studies from manufacturing, logistics, healthcare, and service industries were chosen. Each case study organization must have implemented or be willing to deploy productivity optimization measures.

The next phase is gathering quantitative and qualitative data from the selected case study organizations. Direct observation, interviews with key staff, and examination of company records and performance measures are some of the data collection methods used. Time and Motion Studies are used to collect precise information on job processes. Surveys are also distributed to employees to gather feedback on ergonomics, workflow efficiency, and the impact of installed tools.

In the upcoming phase, acquired data is evaluated using a variety of statistical and analytical methods. To detect patterns and correlations, descriptive and inferential statistics are applied to quantitative data from Time and Motion Studies as well as performance measurements. Thematic analysis is used to discover common themes and insights in qualitative data gathered through interviews and surveys. The investigation tries to identify inefficiencies, assess the impact of various tools, and evaluate the effectiveness of case studies.



The next phase focuses on the practical application of selected industrial engineering tools and procedures in the case study organizations. Based on data analysis insights, particular tools like as Lean methodologies, Six Sigma projects, ergonomic interventions, and JIT processes are developed and implemented to address identified inefficiencies. Implementation plans are created in partnership with organizations, outlining procedures, dates, and accountable persons. Pilot projects are launched to evaluate the usefulness of these tools prior to full-scale implementation.

The final phase entails assessing the effectiveness of the implemented tools and approaches. This includes gathering performance data again and performing follow-up interviews and surveys to evaluate changes in productivity, quality, and employee satisfaction. To assess the effectiveness of interventions, a comparative analysis is performed on pre- and post-implementation measures. The evaluation also takes into account employee and management comments to better understand each tool's real obstacles and benefits. The findings are analyzed to form conclusions regarding the overall efficacy of industrial engineering approaches in increasing productivity and to make recommendations for future applications.

This organized technique ensures a methodical and complete approach to understanding and increasing productivity using industrial engineering technologies. This study attempts to give strong and actionable conclusions that may be implemented across a variety of businesses by combining theoretical insights with practical case studies.

5. Discussion

The findings of this study highlight the tremendous impact that industrial engineering tools and procedures may have on productivity optimization across a variety of industries. The use of these approaches, as described in the case studies, gives various important insights into their effectiveness and practical obstacles. This talk synthesizes these discoveries, comparing theoretical assumptions to empirical findings, and delves into the broader implications for practice and future research.

The adoption of Time and Motion Studies in the case studies resulted in significant increases in task efficiency and workflow optimization. Organizations were able to discover and eliminate superfluous motions and redundant jobs after rigorously studying and simplifying business processes. This led in shorter cycle durations and higher overall output. Lean Manufacturing approaches, particularly 5S and Value Stream Mapping (VSM), aided these gains. The systematic approach to waste reduction included in Lean principles resulted in better structured and efficient workplaces. The case studies supported the theoretical premise that Lean Manufacturing's emphasis on continuous improvement (Kaizen) promotes a culture of long-term efficiency and productivity.

Six Sigma approaches, notably the DMAIC framework, have proven extremely effective in reducing process variability and improving quality. The case studies demonstrated that by thoroughly evaluating data and using Six Sigma tools such as Pareto charts and fishbone diagrams, firms may identify the fundamental causes of errors and variability. Implementing Six Sigma initiatives led in verifiable improvements in product quality and process consistency, supporting the theoretical claims of significant defect reduction and cost reductions. However, the case studies also showed the difficulty of obtaining buy-in from all organizational levels, which is critical to the success of Six Sigma programs.

Ergonomics were crucial in increasing worker productivity and reducing fatigue-related errors. The ergonomic adjustments adapted to the unique demands of the workers in the case studies resulted in considerable increases in employee happiness and productivity. These findings are consistent with the theoretical paradigm, which suggests that well-designed workspaces contribute to improved health outcomes and efficiency. On the other hand, the use of Just-In-Time (JIT) Production demonstrated its ability to cut inventory costs and lead time. The synchronization of production schedules with actual demand reduced waste and increased responsiveness. However, the case studies demonstrated JIT systems' susceptibility to supply chain disruptions, underlining the importance of comprehensive contingency planning.

Total Quality Management (TQM) originated as a comprehensive framework for incorporating quality into all aspects of business operations. The case studies proved that TQM principles, such as customer focus and continuous improvement, result in overall performance improvements. Organizations that successfully implemented TQM techniques experienced considerable increases in customer satisfaction and operational efficiency. Supply Chain Optimization, which draws on principles from operations research and systems theory, improved these results by guaranteeing effective coordination and integration of supply chain activities. The actual evidence from the case studies indicated that efficient supply chains improve resource utilization and adaptability in fulfilling market needs.

Simulation modeling gave useful insights into process optimization via virtual experimentation. The case studies demonstrated that simulation tools enabled firms to test numerous scenarios and forecast outcomes while avoiding the dangers associated with real-world trials. This capacity to predict the impact of modifications prior to implementation proven especially useful in complicated and dynamic contexts. The theoretical advantage of reduced risk and informed decision-making was clear, as firms were able to adapt their processes based on simulation results, resulting in improved performance and fewer operational uncertainties.

Overall, the study emphasizes the numerous advantages of using industrial engineering methods for productivity enhancement. Each technique, from Time and Motion Studies to Simulation Modelling, makes a unique contribution to improving efficiency, quality, and responsiveness. The integration of various tools inside a cohesive framework, as demonstrated in the case studies, results in synergistic benefits that boost productivity. However, the study emphasizes the relevance of corporate culture, leadership commitment, and employee involvement in ensuring the successful application of these techniques. Future research should concentrate on establishing strategies to address implementation obstacles, notably in gaining stakeholder support and managing change. Additionally, investigating the possibilities of emerging technologies such as artificial intelligence and advanced analytics in conjunction with classic industrial engineering techniques may open up new options for efficiency optimization. The findings of this study lay a solid platform for practitioners and scholars to build on, opening the road for continual improvement in industrial processes.

6. Conclusion

This research demonstrates the significant benefits of using industrial engineering tools and techniques to optimize productivity across various industries. Key methods such as Time and Motion Studies, Lean Manufacturing, Six Sigma, Ergonomics, Just-In-Time (JIT) Production, Total Quality Management (TQM), Supply Chain Optimization, and Simulation Modeling each contribute uniquely to improving efficiency, reducing waste, and enhancing quality.

Time and Motion Studies and Lean Manufacturing streamline processes and eliminate unnecessary tasks, leading to faster and more efficient workflows. Six Sigma helps in reducing defects and ensuring consistency, while Ergonomics improves worker comfort and performance. JIT Production minimizes inventory costs and enhances responsiveness to demand.

TQM offers a comprehensive approach to embedding quality in every aspect of operations, and Supply Chain Optimization ensures efficient coordination of resources. Simulation Modeling allows organizations to test changes in a virtual environment, reducing risks and enhancing decision-making.

The case studies show that these tools, when implemented effectively, lead to significant productivity gains. However, successful implementation requires strong leadership, a supportive organizational culture, and active employee participation. Future research should explore strategies to overcome implementation challenges and investigate the potential of combining traditional methods with new technologies.

In conclusion, industrial engineering tools and techniques provide a powerful framework for achieving sustained productivity improvements and operational excellence in various industries.

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