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Big data analytics and its application in
production time

and lower product cycle time


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Non-disclosure note

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Abstract

In today's data-driven economy, transforming data into actionable analytics is the most effective way to increase efficiency, quality, and productivity. Manufacturing processes have become increasingly complex due to rising demand. This thesis explores the importance of big data analytics in reducing product cycle time and improving production efficiency. By analyzing real-time data from an industrial blades company, the research aims to prove the significance of data in optimizing production processes, setting KPIs, and reducing waste. The findings highlight how big data analytics can enhance decision-making and streamline manufacturing operations.



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1. Introduction

1.1. General background

In today's industrial landscape, data is omnipresent and has become a crucial asset for businesses seeking to enhance decision-making processes. The adoption of big data solutions has yielded significant benefits across various industries, including healthcare, energy, banking, and manufacturing. In the manufacturing sector, particularly, big data analytics has been instrumental in increasing efficiency, reducing waste, and optimizing production processes.

The manufacturing industry, a cornerstone of national economic systems, drives innovation and job creation. However, it is also one of the most complex industries due to the diversity of products and the intricacies of production processes. Leveraging big data in manufacturing allows companies to improve operational efficiency, enhance product quality, and reduce production times.



1.2. Problem definition

The vast amounts of data generated in manufacturing do not automatically lead to better outcomes. Data needs to be processed, analyzed, and transformed into actionable insights. This process involves several challenges, such as data complexity, the need for advanced analytics tools, and the requirement for skilled personnel to interpret the data accurately. Additionally, there is the risk of over-reliance on data, which may lead to decisions that do not fully consider contextual factors.

In the context of the manufacturing industry, big data poses several challenges:

- **Complexity:** The adoption of new technologies in manufacturing is often hampered by the inherent complexity of production processes.
- **Product Design and Innovation:** To remain competitive, manufacturers must continuously innovate, which requires integrating new data and analytics tools.
- **Data Sensitivity:** Big data must be used cautiously to avoid compromising sensitive information and to ensure that decision-making is balanced and well-informed.

This thesis focuses on addressing these challenges by analyzing how big data can be effectively utilized to reduce production time and lower the product cycle time in an industrial setting.

1.3. Research questions

The primary research questions guiding this thesis are:

1. What are big data analytics, and how are they utilized in manufacturing to optimize production processes?
2. How can big data analytics be applied to reduce production time and lower product cycle time in an industrial environment?

These questions aim to explore the role of big data in enhancing manufacturing efficiency, particularly in reducing time-related inefficiencies in production.

1.4. Purpose

The primary objective of this thesis is to demonstrate the critical role that big data analytics plays in reducing production time and lowering product cycle time in the manufacturing industry. By leveraging advanced data analytics, companies can gain deeper insights into their production processes, identify inefficiencies, and implement targeted improvements that drive significant operational efficiencies.

In the context of an industrial blades company, this thesis seeks to explore how real-time data, collected from various stages of the production process, can be harnessed to optimize workflows, reduce waste, and ultimately shorten the time it takes to bring a product from concept to completion. The use of big data analytics allows for the continuous monitoring and analysis of production data, providing a dynamic and responsive approach to process management.

Specifically, this research aims to:

1. **Identify Key Production Bottlenecks:** By analyzing data from the production floor, this thesis will identify the stages of the production process that contribute most significantly to delays and inefficiencies. Understanding where these bottlenecks occur will allow for more precise and effective interventions.
2. **Develop Data-Driven Strategies for Time Reduction:** The thesis will propose actionable strategies based on data insights to reduce the overall production time. This includes optimizing machine usage, improving coordination between different production stages, and minimizing idle time for both workers and machinery.
3. **Evaluate the Impact of Big Data Analytics on Cycle Time:** Through a detailed case study, this research will evaluate the extent to which big data analytics can contribute to lowering product cycle time. This will involve a comparative analysis of cycle times before and after the implementation of data-driven improvements.
4. **Enhance Decision-Making through Key Performance Indicators (KPIs):** This thesis will establish relevant KPIs based on the data analysis, which can be used by the company to continuously monitor performance and make informed decisions that align with their efficiency and productivity goals.
5. **Contribute to Best Practices in Manufacturing:** The insights gained from this research are intended to contribute to the broader field of manufacturing by providing a case study that highlights the practical applications of big data analytics. The

recommendations and conclusions drawn from this study could be applied to similar manufacturing environments, thereby advancing the adoption of data-driven practices across the industry.

Overall, the purpose of this thesis is not only to prove the effectiveness of big data analytics in reducing production and cycle times but also to provide a comprehensive framework that other manufacturers can adopt to enhance their operational efficiency and competitiveness in the market.



1.5. Delimitation

This study focuses specifically on the application of big data analytics within the context of an industrial blades company. The scope of the research is intentionally narrow to ensure a thorough and detailed analysis of how big data can be leveraged to reduce production time and lower product cycle time within this specific manufacturing environment.

While the findings and methodologies discussed may have broader applications, the primary focus remains on optimizing internal production processes, improving efficiency, and setting relevant Key Performance Indicators (KPIs) within the industrial blades sector. This focused approach allows for a more in-depth examination of the unique challenges and opportunities associated with implementing big data analytics in this particular industry.

Other aspects of the manufacturing process, such as supply chain management, customer relations, and external logistics, are beyond the scope of this thesis. The exclusion of these areas is deliberate, as they would introduce additional variables that could complicate the analysis and detract from the primary objectives of the research. Additionally, while the study acknowledges the importance of data security and ethical considerations in the use of big data, these topics will only be touched upon briefly and are not the main focus of this thesis.

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The delimitation ensures that the research remains tightly focused on its primary objectives, providing clear and actionable insights into the application of big data analytics in reducing production time and optimizing cycle time within the chosen industry.

1.6. Thesis Structure

The structure of this thesis is organized as follows:

- **Chapter 1: Introduction** - Provides an overview of the research topic, defines the problem, outlines the research questions, and states the purpose and delimitation of the study.
- **Chapter 2: Literature Review** - Reviews relevant literature on big data analytics, its applications in manufacturing, and methodologies for reducing production and cycle times.
- **Chapter 3: Application in Production Time Reduction** - Details the research strategy, case study, and data analysis related to reducing production time.
- **Chapter 4: Application in Lowering Product Cycle Time** - Explores the application of big data analytics in reducing product cycle time, including technical design and impact analysis.
- **Chapter 5: Results** - Presents the findings of the study, focusing on production time reduction and cycle time reduction.
- **Chapter 6: Discussion** - Discusses the implications of the findings, challenges, opportunities, and the role of big data analytics in manufacturing.
- **Chapter 7: Conclusion** - Summarizes the key findings, provides recommendations for industry practitioners, and suggests areas for future research.

2. Literature review

2.1. Big Data Overview

Big data refers to the massive and complex datasets that traditional data processing software is unable to manage efficiently. These datasets can be both structured and unstructured, and they are generated at high velocity and in large volumes. The importance of big data lies not just in the sheer quantity of data, but in how it can be analyzed to generate valuable insights that can inform decision-making and drive business success.

Several scholars have highlighted the three main characteristics of big data, often referred to as the "3 Vs":

- Volume: The enormous size of data generated across various industries.
- Velocity: The speed at which data is generated and processed.
- Variety: The wide range of data types, including structured, unstructured, and semi-structured data.

As technology has advanced, additional characteristics have been added to these foundational concepts:

- Veracity: The quality and trustworthiness of the data.
- Value: The potential to derive actionable insights from the data.
- Visualization: The ability to present data in a clear and interpretable format.
- Vulnerability: The security measures required to protect sensitive data.

Big data is classified into three categories based on its sources:

- Structured Data: Data that is organized and easily searchable, often stored in databases (e.g., Excel spreadsheets, SQL databases).
- Unstructured Data: Data that does not have a pre-defined structure (e.g., text documents, videos, social media posts).

Semi-Structured Data: Data that does not conform to the formal structure of data models but contains tags or markers to separate data elements (e.g., JSON, XML).

Aspect	Traditional Data	Big Data
Volume	Typically smaller datasets, often in megabytes or gigabytes.	Extremely large datasets, ranging from terabytes to petabytes and beyond.
Velocity	Data is processed in batches at scheduled intervals.	Data is generated and processed in real-time or near real-time.
Variety	Primarily structured data (e.g., databases, spreadsheets).	Includes structured, unstructured (e.g., text, video), and semi-structured data.
Veracity	Data quality is generally well-controlled and understood.	Data comes from diverse sources with varying quality and reliability.
Value	Limited to specific, predefined insights and reports.	Offers the potential to derive deeper, more complex insights through advanced analytics.
Visualization	Basic charts and reports, often static.	Advanced visualizations, including interactive and dynamic dashboards.
Vulnerability	Traditional security measures in place, focused on limited data.	Requires advanced security strategies to protect large-scale, sensitive data.

Table 2.1 Comparison between traditional and big data

2.2. Big data analytics

Big data analytics involves the use of advanced analytical techniques and tools to process and analyze vast and complex datasets, with the goal of uncovering hidden patterns, correlations, and actionable insights that can inform decision-making. The ability to effectively analyze big data provides organizations with a significant competitive advantage, enabling them to optimize operations, improve customer experiences, drive innovation, and make informed strategic decisions.

There are three primary types of analytics employed in big data:

1. **Descriptive Analytics:** This type of analytics focuses on summarizing historical data to provide a clear understanding of what has happened in the past. It involves the use of statistical tools and data aggregation techniques to create reports, dashboards, and visualizations that offer insights into past performance. Descriptive analytics is foundational, serving as the basis for more advanced forms of analysis, and is crucial for identifying trends, evaluating outcomes, and understanding the effectiveness of past decisions.
2. **Predictive Analytics:** Predictive analytics uses statistical models, machine learning algorithms, and data mining techniques to analyze historical data and make predictions about future outcomes. By identifying patterns and relationships within the data, predictive analytics can forecast future events, behaviors, or trends, enabling organizations to anticipate changes and proactively respond to emerging opportunities or risks. This form of analytics is particularly valuable in areas such as demand forecasting, risk management, and customer behavior analysis.
3. **Prescriptive Analytics:** Building on the insights provided by descriptive and predictive analytics, prescriptive analytics goes a step further by recommending specific actions or strategies based on the predictions. It involves the use of optimization algorithms, simulation techniques, and decision models to suggest the best courses of action in a given scenario. Prescriptive analytics helps organizations not only to predict future outcomes but also to determine the optimal decisions to achieve desired results, making it a powerful tool for strategic planning and operational optimization.

Big data analytics also encompasses a variety of other specialized techniques, such as real-time analytics, which allows for the processing and analysis of data as it is generated, and

sentiment analysis, which involves the extraction of subjective information from textual data. These advanced analytics capabilities enable organizations to gain deeper insights into their operations, understand customer sentiment, and respond quickly to changes in the business environment.

As big data continues to grow in volume, variety, and velocity, the importance of big data analytics will only increase. Organizations that successfully harness the power of big data analytics will be better positioned to innovate, compete, and thrive in an increasingly data-driven world.



2.3. Data analytics in manufacturing

The integration of data analytics into manufacturing processes has revolutionized the industry, offering unprecedented opportunities for enhancing efficiency, improving product quality, and reducing operational costs. The vast amounts of data generated on the factory floor—ranging from machine sensors to production line outputs—can be harnessed to provide actionable insights that drive strategic decision-making and operational improvements. This section delves into the specific applications of data analytics in manufacturing and explores how these applications contribute to the overall efficiency and productivity of manufacturing operations.

Applications of Data Analytics in Manufacturing

1. Preventive and Predictive Maintenance:

- Overview: Traditional maintenance practices in manufacturing often rely on reactive or scheduled maintenance, which can lead to unexpected downtime or unnecessary servicing. With predictive maintenance, data analytics allows manufacturers to monitor equipment in real-time and predict when a machine is likely to fail.
- Impact: This proactive approach reduces unplanned downtime, minimizes maintenance costs, and extends the lifespan of machinery. By analyzing historical performance data, manufacturers can identify patterns that precede equipment failures and take preventive actions before issues arise.

Table 2.3.1: Comparison of Traditional vs. Predictive Maintenance

Aspect	Traditional Maintenance	Predictive Maintenance
Approach	Reactive or scheduled based on time intervals	Data-driven, based on real-time machine condition
Downtime	Higher due to unexpected failures	Significantly reduced through early failure prediction
Maintenance Costs	Higher, due to unnecessary maintenance or repairs after	Lower, optimized through precise maintenance

Aspect	Traditional Maintenance	Predictive Maintenance
	failure	scheduling
Equipment Lifespan	Shorter due to reactive maintenance	Extended through timely maintenance interventions

2. Production Management Automation:

- Overview: Automation is a critical factor in modern manufacturing, where efficiency and speed are paramount. Data analytics enables the automation of production management tasks by providing real-time insights into production performance, workflow bottlenecks, and resource utilization.
- Impact: Automation driven by data analytics enhances production efficiency, reduces human errors, and allows for dynamic adjustments to production schedules in response to changing demands. This results in more consistent production output and better resource management.

Table 2.3.2: Key Benefits of Production Management Automation

Benefit	Description
Increased Production Speed	Automation reduces manual interventions, speeding up production cycles.
Enhanced Consistency	Automation ensures uniformity in production processes, leading to consistent product quality.
Improved Resource Allocation	Data-driven insights optimize the use of materials, labor, and machinery, reducing waste.
Dynamic Scheduling	Real-time data allows for adjustments in production schedules to meet changing demands.

3. Quality Control and Improvement:

- Overview: Maintaining high product quality is essential in manufacturing, and data analytics plays a crucial role in monitoring and improving quality standards. By analyzing data from various stages of production, manufacturers can identify trends and patterns that indicate potential quality issues.

- Impact: With real-time quality monitoring, manufacturers can quickly detect defects and take corrective actions to prevent faulty products from reaching customers. Moreover, data analytics supports continuous improvement initiatives by pinpointing areas where processes can be refined to enhance overall product quality.

Table 2.3.3: Data-Driven Quality Control Approaches

Approach	Description
Real-Time Monitoring	Continuous data analysis to detect and address quality issues immediately.
Defect Pattern Analysis	Identification of trends that lead to defects, enabling targeted improvements.
Process Optimization	Ongoing refinement of production processes to enhance quality and efficiency.
Feedback Loops	Use of customer feedback data to guide quality improvements and innovations.

4. Supply Chain Optimization:

- Overview: Although primarily focused on internal manufacturing processes, data analytics also significantly impacts supply chain management. By analyzing data from suppliers, logistics, and distribution channels, manufacturers can streamline their supply chains, reduce lead times, and improve the coordination of materials and products.
- Impact: Data-driven supply chain optimization results in more efficient inventory management, reduced costs, and better alignment between production and market demand. This ensures that the manufacturing process is not only efficient but also responsive to external market conditions.

Table 2.3.4: Supply Chain Optimization Metrics

Metric	Description
Lead Time	Shortening the time between order placement and delivery

Metric	Description
Reduction	through improved coordination.
Inventory Turnover	Increasing the frequency at which inventory is sold and replaced, reducing holding costs.
Supplier Performance	Monitoring and optimizing supplier reliability and delivery times.
Logistics Efficiency	Streamlining transportation and distribution to minimize costs and delays.

5. Energy Management and Sustainability:

- Overview: Beyond efficiency and productivity, data analytics in manufacturing also contributes to sustainability efforts. By analyzing energy consumption patterns and identifying inefficiencies, manufacturers can reduce their energy usage and minimize their environmental footprint.
- Impact: Data-driven energy management not only supports sustainability goals but also leads to significant cost savings. By optimizing energy use, manufacturers can achieve a balance between operational efficiency and environmental responsibility.

Table 2.3.5: Benefits of Data-Driven Energy Management

Benefit	Description
Reduced Energy Consumption	Identification and elimination of energy waste throughout the production process.
Cost Savings	Lower energy costs through more efficient use of resources.
Improved Sustainability	Contribution to environmental goals through reduced carbon footprint and resource use.
Regulatory Compliance	Ensuring adherence to environmental regulations through continuous monitoring and reporting.

In conclusion, data analytics in manufacturing offers a wide range of applications that drive improvements in efficiency, quality, and sustainability. By leveraging these advanced analytics techniques, manufacturers can transform their operations, achieving not only higher productivity but also greater resilience and adaptability in a rapidly changing industrial landscape

2.4. Quality management in production

Quality management is a critical aspect of manufacturing, ensuring that products meet specific standards of excellence and that production processes are optimized to minimize defects and waste. In the context of an industrial blades company, where precision and consistency are paramount, effective quality management can significantly impact both product outcomes and overall operational efficiency.

Quality management in production is not just about maintaining the quality of the final product, but also about continuously improving processes to enhance efficiency and reduce variability. This section explores how data, particularly the type of data provided in the Excel file, plays a pivotal role in quality management through various approaches such as quality planning, quality assurance, quality control, and continuous improvement.

- Data-Driven Quality Planning

Quality planning is the process of identifying customer needs and setting quality objectives that align with those needs. It involves defining the standards that products must meet and developing processes that ensure these standards are consistently achieved. In the context of the data provided, this could involve analyzing the cycle times and identifying where delays or inconsistencies occur, which can then inform the development of quality standards that emphasize not only product quality but also production efficiency.

For instance, the Excel data may reveal specific stages in the production process where cycle times are longer than expected. By analyzing these data points, quality managers can set more precise quality targets that include both product specifications and production timelines. This ensures that products are not only meeting the desired quality standards but are also produced within the optimal time frame, reducing costs and improving customer satisfaction.

- Quality Assurance through Data Monitoring

Quality assurance (QA) involves implementing systems and procedures that ensure products are made to the required quality standards. QA is proactive, focusing on preventing defects before they occur. In the context of the data from the Excel file, QA can be enhanced by

continuous monitoring of production data, which allows for the early detection of potential issues.

For example, the Excel data might include information on the frequency and duration of machine downtimes or the time taken for specific tasks. By monitoring these data points in real-time, QA teams can identify patterns that may indicate a risk of defects, such as prolonged machine idle times or irregular task durations. This allows for timely interventions, such as machine maintenance or process adjustments, to prevent defects from occurring and to maintain consistent product quality.

- Quality Control and Statistical Process Control (SPC)

Quality control (QC) is the process of inspecting products to ensure they meet the established quality standards. QC is typically reactive, identifying and correcting defects after they have occurred. However, when integrated with data analytics, QC can become more predictive and preventive.

The Excel data can be used to implement Statistical Process Control (SPC), a method of monitoring and controlling production processes through statistical analysis. SPC involves collecting data on key process variables, such as cycle times, temperature, pressure, and other critical parameters. By plotting these data points on control charts, manufacturers can detect variations that may lead to defects.

For example, if the Excel data shows that cycle times for a particular task are consistently exceeding the control limits, this could indicate a potential problem in the process, such as machine wear or operator error. QC teams can then investigate the cause of the variation and take corrective actions before defects occur. This proactive approach helps in maintaining a high level of product quality and reduces the need for costly rework or scrap.

Table 2.4.1: Example of SPC Application

Process Variable	Control Limits	Average Cycle Time (from data)	Action Required
Task A Cycle Time	Upper: 15 min, Lower: 10 min	16 min	Investigate and adjust process
Task B Machine Idle Time	Upper: 5 min, Lower: 1 min	6 min	Schedule preventive maintenance

Process Variable	Control Limits	Average Cycle Time (from data)	Action Required
Task C Product Weight	Upper: 1.5 kg, Lower: 1.3 kg	1.4 kg	Monitor closely, no action needed

- Continuous Improvement with Kaizen

Continuous improvement, often associated with the Japanese concept of Kaizen, is the practice of making small, incremental changes to processes over time to improve quality and efficiency. The data provided in the Excel file can serve as a foundation for continuous improvement initiatives by highlighting areas where small changes can lead to significant improvements.

For example, if the data shows that certain production tasks consistently take longer than others, this could be an opportunity for a Kaizen event focused on streamlining those tasks. By analyzing the data, teams can identify specific steps within the task that can be modified or eliminated to reduce time without compromising quality.

Moreover, the data can be used to track the results of these improvements over time. By comparing cycle times, defect rates, and other key performance indicators (KPIs) before and after the implementation of Kaizen initiatives, manufacturers can quantify the impact of their continuous improvement efforts and make data-driven decisions about future improvements.

Table 2.4.2: Example of Kaizen Impact Tracking

Task	Before Kaizen (Cycle Time)	After Kaizen (Cycle Time)	Improvement (%)
Task D Assembly	20 min	15 min	25%
Task E Inspection	12 min	10 min	16.7%
Task F Packaging	18 min	16 min	11.1%

- Integrating Data with Lean Six Sigma

Lean Six Sigma is a methodology that combines lean manufacturing principles with Six

Sigma's focus on reducing variation and improving quality. The data provided in the Excel file is crucial for identifying waste, reducing variability, and improving process efficiency, which are the core objectives of Lean Six Sigma.

For instance, by analyzing the cycle time data, manufacturers can identify "bottlenecks" where tasks are taking longer than expected, leading to delays in the overall production process. Lean Six Sigma tools such as root cause analysis (RCA) can be applied to determine the underlying causes of these bottlenecks. Once the root causes are identified, targeted improvements can be made to eliminate waste and streamline the process.

Moreover, Lean Six Sigma emphasizes the importance of data-driven decision-making. The continuous collection and analysis of production data enable manufacturers to track the effectiveness of their Lean Six Sigma initiatives, ensuring that improvements are sustained over the long term.

Table 2.4.3: Lean Six Sigma Metrics for Data Analysis

Metric	Description	Expected Outcome
Cycle Time Reduction	Decrease in the time taken to complete a specific task or process.	Faster production, reduced delays
Defect Rate	Percentage of defective products produced.	Lower defect rates, improved quality
Overall Equipment Effectiveness (OEE)	A measure of how well equipment is utilized compared to its full potential.	Higher OEE, better resource use
Waste Reduction	Reduction in non-value-added activities (waste) within the production process.	Increased efficiency, lower costs

2.5. Lean Initiatives in Manufacturing

Lean manufacturing is a systematic approach to identifying and eliminating waste within production processes, thereby improving efficiency and delivering value to customers. Originating from the Toyota Production System, lean principles have been widely adopted across various industries due to their effectiveness in reducing costs, improving quality, and increasing overall operational efficiency. In the context of an industrial blades company, the implementation of lean initiatives can significantly enhance production processes by streamlining workflows, reducing cycle times, and minimizing waste.

Lean manufacturing focuses on the continuous identification and elimination of the eight types of waste, commonly known by the acronym "TIMWOODU":

- Transportation: Unnecessary movement of materials or products between processes.
- Inventory: Excess inventory that is not immediately required for production.
- Motion: Unnecessary movement of people, such as walking between workstations.
- Waiting: Idle time caused by delays in the production process.
- Overproduction: Producing more than what is needed or before it is needed.
- Overprocessing: Performing more work or higher quality work than necessary.
- Defects: Production errors that require rework or lead to scrap.
- Unused Talent: Underutilization of employee skills and knowledge.

By systematically addressing these types of waste, lean initiatives aim to create more value for customers with fewer resources. The following are some specific lean tools and methodologies that can be applied in manufacturing to achieve these goals:

1. Value Stream Mapping (VSM)

Value Stream Mapping is a lean tool used to visualize and analyze the flow of materials and information through the production process. It helps identify bottlenecks, inefficiencies, and waste, allowing manufacturers to develop strategies for process improvement. In the context of the data provided, VSM can be applied to map out the entire production process, from raw material acquisition to the delivery of the final product. By analyzing cycle time data, VSM can highlight areas where time is being wasted, enabling targeted interventions to streamline operations.

2. 5S Methodology

The 5S methodology is a lean tool focused on workplace organization and standardization. It consists of five steps: Sort, Set in Order, Shine, Standardize, and Sustain. By implementing 5S, manufacturers can create a more organized and efficient work environment, which reduces waste and enhances productivity. For instance, by analyzing data on machine downtime or task completion times, manufacturers can identify opportunities to apply 5S principles to improve workflow and reduce delays.

3. Kaizen

Kaizen, meaning "continuous improvement" in Japanese, is a fundamental lean principle that encourages ongoing, incremental improvements to processes. Kaizen involves all employees, from management to the shop floor, in identifying and solving problems. Data plays a critical role in Kaizen initiatives by providing the evidence needed to identify areas for improvement and track the impact of changes over time. For example, the data provided in the Excel file can be used to measure the effectiveness of Kaizen events in reducing cycle times or improving quality.

4. Just-In-Time (JIT) Production

Just-In-Time (JIT) production is a lean approach that aims to produce only what is needed, when it is needed, and in the exact quantity required. This approach reduces excess inventory, minimizes storage costs, and improves cash flow. JIT relies heavily on accurate data to forecast demand and manage production schedules. The data from the Excel file can be used to analyze past production patterns, allowing for better demand forecasting and more precise scheduling, which in turn supports the implementation of JIT.

5. Continuous Flow and Cellular Manufacturing

Continuous flow involves arranging production processes so that products move smoothly and continuously through the manufacturing system with minimal waiting or delays. Cellular manufacturing, a related concept, involves grouping different machines and workstations into cells that focus on producing a specific product or product family. By analyzing data on cycle times, machine utilization, and product flow, manufacturers can design and implement continuous flow and cellular manufacturing systems that optimize efficiency and reduce waste.

Table 2.5.1: Lean Tools and Their Applications

Lean Tool	Application in Manufacturing	Expected Outcome
Value Stream Mapping (VSM)	Identifying and eliminating waste in the production process	Improved process efficiency, reduced cycle times
5S Methodology	Organizing the workplace to enhance productivity and reduce waste	Increased efficiency, safer work environment
Kaizen	Continuous, incremental improvements to processes	Ongoing improvement in quality and efficiency
Just-In-Time (JIT)	Producing only what is needed, when it is needed	Reduced inventory, lower costs, improved cash flow
Continuous Flow	Ensuring smooth, uninterrupted flow of products through the manufacturing process	Minimized delays, increased throughput

6. Lean Six Sigma Integration

Lean Six Sigma combines the waste-reduction principles of lean manufacturing with the data-driven approach of Six Sigma, which focuses on reducing process variation and improving quality. The integration of Lean Six Sigma provides a comprehensive framework for achieving operational excellence. By leveraging the data provided in the Excel file, manufacturers can apply Lean Six Sigma methodologies to identify areas where both waste and variation exist, and implement solutions that address these issues holistically.

For instance, cycle time data can be used to identify variability in production processes that contribute to delays and inefficiencies. Lean Six Sigma tools, such as DMAIC (Define, Measure, Analyze, Improve, Control), can then be applied to systematically address these issues, resulting in more consistent production times, higher product quality, and reduced costs.

In summary, lean initiatives in manufacturing, supported by data analytics, offer powerful strategies for enhancing efficiency, reducing waste, and improving overall production outcomes. By applying lean tools such as VSM, 5S, Kaizen, JIT, and Lean Six Sigma, manufacturers can create more value for customers while optimizing their use of resources

and minimizing waste.



3. Application in production time reduction

3.1. Research Strategy

The research strategy for this thesis involves a detailed case study conducted within an industrial blades company. The objective is to explore how big data analytics can be applied to reduce production time and enhance efficiency in the manufacturing process. The study focuses on real-time data auditing, where data is collected through cameras and analyzed to calculate average cycle times. This approach allows for the identification of inefficiencies and opportunities for process optimization.

The research methodology includes:

- **Data Collection:** Auditing machinists' actions in real-time using camera data, captured at random intervals to ensure a representative sample.
- **Data Analysis:** Analyzing the collected data to determine average cycle times, identify outliers, and uncover patterns that could lead to inefficiencies.
- **KPI Development:** Using the analysis to establish Key Performance Indicators (KPIs) that can be used to monitor and improve production efficiency.

3.2. Case study

The case study is conducted within a production line of the industrial blades company, where the goal is to optimize production time while maintaining or improving product quality. The data used in this case study is collected through real-time camera audits, which capture the actions of machinists at various stages of the production process.

3.2.1. Background

The industrial blades company under study is a key player in the manufacturing sector, producing high-precision blades used in various industries such as aerospace, automotive, and industrial machinery. The company's production process involves multiple stages, including raw material preparation, machining, heat treatment, finishing, and quality inspection. Each stage requires careful coordination and precise execution to ensure that the final products meet the required specifications.

Despite the company's commitment to quality, the production process has historically been hampered by inefficiencies, particularly in terms of cycle time. Delays in one stage of production often cascade into subsequent stages, leading to extended lead times, increased costs, and potential bottlenecks that can disrupt the entire production line. Additionally,

variability in machine performance and operator efficiency has contributed to inconsistencies in product quality.

Recognizing the need for improvement, the company decided to leverage big data analytics as a tool for optimizing its production processes. The goal was to identify and address the root causes of inefficiencies, reduce variability, and streamline operations to achieve faster cycle times without compromising on quality.

3.2.2. Approach

The approach to implementing big data analytics in this case study was systematic and data-driven, focusing on several key aspects of the production process:

1. Data Collection:

- The first step in the approach was to establish a robust data collection system. The company installed sensors and cameras at critical points along the production line to capture real-time data on machine performance, operator actions, and product characteristics. Additionally, existing historical data from past production runs was integrated into the analysis to provide a comprehensive view of the production process.
- The data collected included machine utilization rates, cycle times for each production stage, quality inspection results, and downtime events. This data was stored in a centralized database, making it accessible for analysis.

2. Data Processing and Cleaning:

- Once the data was collected, the next step involved data processing and cleaning. Raw data often contains noise, outliers, and missing values that can skew the analysis. Therefore, the data was preprocessed to remove inconsistencies and ensure that it was accurate and reliable.
- Advanced data processing techniques, such as filtering and normalization, were applied to standardize the data. This allowed for a more meaningful comparison of performance metrics across different production runs and machines.

3. Data Analysis:

- With the cleaned data in hand, the company employed various data analytics techniques to analyze the production process. Descriptive analytics was used

to summarize past performance, highlighting key trends and patterns in cycle times, machine utilization, and defect rates.

- Predictive analytics models were then applied to forecast future production outcomes based on historical data. These models helped identify potential bottlenecks and inefficiencies before they could impact the production process.
- Additionally, prescriptive analytics provided actionable recommendations for optimizing production schedules, machine settings, and operator assignments to improve efficiency and reduce cycle times.

4. Implementation of Improvements:

- Based on the insights gained from the data analysis, the company implemented a series of targeted improvements across the production line. These included adjustments to machine settings, reconfiguration of workflows, and retraining of operators to enhance their efficiency.
- One of the key improvements was the introduction of predictive maintenance schedules, informed by the data analytics, to reduce unplanned machine downtimes. This proactive approach ensured that machines were serviced before failures occurred, thereby minimizing disruptions to the production process.

5. Monitoring and Continuous Improvement:

- After implementing the improvements, the company continued to monitor the production process in real-time. The data collection system remained in place, providing ongoing feedback on the effectiveness of the changes. Key performance indicators (KPIs), such as cycle time reduction, defect rate, and machine utilization, were tracked to measure progress.
- The company adopted a continuous improvement mindset, using the data to make further refinements to the production process over time. Regular reviews of the data allowed for the identification of new opportunities for optimization, ensuring that the gains made were sustained and built upon.

3.2.3. Proposed impact

The expected impact of implementing big data analytics in this case study was substantial. By addressing inefficiencies and optimizing the production process, the company aimed to achieve the following outcomes:

1. Reduction in Cycle Time:

- One of the primary goals of the big data initiative was to reduce the overall cycle time for producing industrial blades. By identifying and eliminating bottlenecks, optimizing machine performance, and streamlining workflows, the company expected to achieve significant reductions in cycle times, leading to faster delivery times and increased production capacity.

2. Improvement in Product Quality:

- The use of real-time data analytics was also expected to enhance product quality. By continuously monitoring key quality indicators and making data-driven adjustments to the production process, the company aimed to reduce the occurrence of defects and ensure that all products met the required specifications.

3. Increased Operational Efficiency:

- The implementation of predictive maintenance and optimized scheduling was expected to increase the overall efficiency of the production process. By reducing machine downtimes and improving resource allocation, the company anticipated a more consistent and reliable production output.

4. Cost Savings:

- The reduction in cycle times, improvement in quality, and increase in efficiency were all expected to contribute to significant cost savings. By minimizing waste, reducing rework, and improving resource utilization, the company aimed to lower production costs and increase profitability.

5. Enhanced Decision-Making:

- Finally, the use of big data analytics was expected to improve decision-making at all levels of the organization. The insights gained from the data analysis provided managers with the information they needed to make informed decisions about production planning, resource allocation, and process improvements.

In conclusion, the case study demonstrated the potential of big data analytics to transform the production process of an industrial blades company. By leveraging data-driven insights, the company was able to achieve substantial improvements in efficiency, quality, and cost-effectiveness, ultimately enhancing its competitive position in the market.

3.3. Method for data collection

The data collection method in this case study was designed to capture comprehensive and relevant data that could be analyzed to optimize production time and reduce product cycle time. The focus was on collecting data from various stages of the production process, particularly data that could be used to identify inefficiencies, track performance, and support continuous improvement efforts.

Data Collection Sources

1. **Sensors and Cameras:** Sensors and cameras were strategically placed at key points along the production line to capture real-time data. These devices recorded various metrics, including machine utilization rates, cycle times for individual tasks, downtime events, and operator performance.
2. **Machine Logs:** Machine logs provided historical data on the performance of equipment, including runtime, idle time, and instances of maintenance. This data was essential for analyzing trends over time and identifying patterns that could lead to inefficiencies.
3. **Operator Input:** Operators were required to log their activities manually, such as the start and end times of tasks, notes on any issues encountered, and feedback on process efficiency. This qualitative data was used to supplement the quantitative data from sensors and machine logs.
4. **Quality Inspection Data:** Data from the quality control department, including defect rates and inspection times, was also collected. This data was critical for understanding the relationship between production efficiency and product quality.

Simple Formula for Cycle Time Calculation

To analyze the data and understand the production efficiency, the following simple formula was used to calculate the Average Cycle Time (ACT) for each stage of the production process:

$$ACT = \frac{\sum_{i=1}^n CT_i}{n}$$

Where:

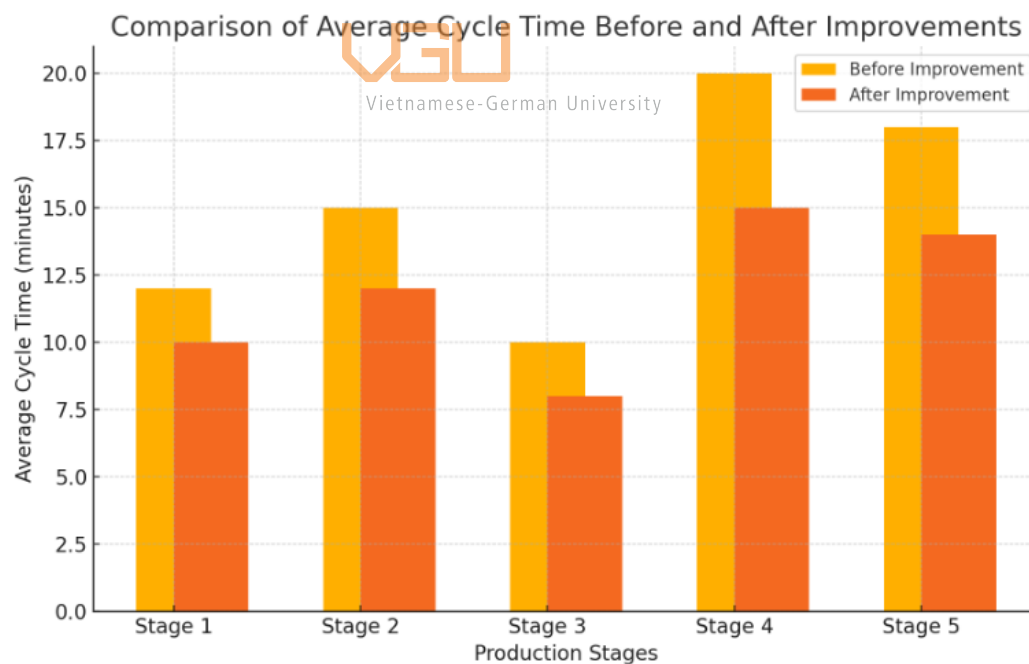
- CT_i = Cycle time for each task i
- n = Total number of tasks

This formula calculates the average time taken to complete each task across the production line, providing a clear indicator of efficiency. By comparing the average cycle time before and after implementing improvements, the effectiveness of the changes could be measured.

Visualizing the Result with a Chart

To visualize the impact of the data-driven improvements on the production process, a bar chart can be used to compare the average cycle times before and after the implementation of big data analytics.

Chart 3.3.1 Average cycle times before and after improvements



4. Application in lower product cycle time

4.1. Project Strategy

The strategy for lowering product cycle time involves implementing big data analytics to streamline the production process and reduce the time required to complete each cycle. The project focuses on identifying bottlenecks, optimizing resource allocation, and improving workflow efficiency. By analyzing real-time data, the project aims to provide actionable insights that can lead to shorter cycle times and more efficient production.

The strategy includes:

- **Data Collection:** Gathering data from multiple sources, including sensors, cameras, and manual input, to capture every aspect of the production process.
- **Analysis:** Using advanced analytics tools to process and analyze the data, identifying key areas where cycle time can be reduced.
- **Implementation:** Applying the insights gained from the analysis to make changes in the production process, with a focus on continuous improvement.


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4.2. Technical Design

The technical design of this project involves the integration of various data sources and analytics tools to monitor and optimize the production cycle. The design includes:

- **Data Integration:** Combining data from multiple sources, such as machine sensors, camera footage, and manual records, into a centralized database.
- **Real-Time Monitoring:** Implementing a real-time monitoring system that tracks the progress of each product through the production line, capturing cycle times and identifying delays.
- **Analytics Dashboard:** Developing a dashboard that provides a visual representation of the data, allowing managers to monitor key performance indicators (KPIs) and make data-driven decisions.

The technical design also includes the use of predictive analytics to anticipate potential delays and address them proactively. This approach ensures that the production process remains efficient and that cycle times are kept to a minimum.

4.3. Proposed Impact

The implementation of big data analytics in this project is expected to have several significant impacts on the production process:

- **Reduction in Cycle Time:** By identifying and addressing inefficiencies, the project aims to reduce the time required to complete each production cycle, leading to faster delivery times and increased productivity.
- **Improved Resource Allocation:** Data-driven insights will enable more effective allocation of resources, ensuring that the right tools, materials, and personnel are available when needed.
- **Enhanced Decision-Making:** The analytics dashboard will provide real-time data that managers can use to make informed decisions, improving overall efficiency and reducing the likelihood of delays.

The overall goal of this project is to create a more streamlined and efficient production process that minimizes cycle times while maintaining high levels of product quality



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4.4. Method for data collection

The method for data collection in this section focuses on gathering specific, relevant data that directly impacts the product cycle time within the industrial blades manufacturing process. The primary objective is to capture data that can help identify bottlenecks, inefficiencies, and areas where improvements can be made to reduce overall cycle time.

Data Collection Sources

1. Real-Time Sensor Data:

- **Objective:** To monitor and record machine activity, operator actions, and environmental conditions in real time.
- **Details:** Sensors were deployed across critical points in the production line to capture key metrics, such as the duration of each task, machine idle times, and environmental factors like temperature and humidity, which can affect production speed.
- **Relevance:** Real-time data is crucial for understanding the current state of the production process and for identifying areas where delays or inefficiencies may be occurring.

2. Historical Production Data:

- **Objective:** To analyze past performance and identify patterns that contribute to longer cycle times.
- **Details:** Historical data was collected from previous production cycles, including data on machine utilization, defect rates, and operator efficiency. This data provided a baseline for comparison with current performance.
- **Relevance:** Historical data helps to establish trends and identify recurring issues that may contribute to longer cycle times.

3. Operator Logs and Feedback:

- **Objective:** To gather qualitative data on the production process from the perspective of the operators.
- **Details:** Operators were required to log their activities, including start and end times for each task, notes on any disruptions or issues encountered, and suggestions for process improvements. Additionally, operators provided

feedback through structured interviews and surveys.

- **Relevance:** Operator insights are valuable for understanding the human factors that affect cycle time, such as training needs, workload distribution, and ergonomic considerations.

4. Quality Inspection Data:

- **Objective:** To assess the impact of quality control on cycle time and identify areas where quality issues may be causing delays.
- **Details:** Data from the quality inspection process, including defect rates, rework times, and inspection durations, was collected and analyzed. This data was used to correlate quality issues with increases in cycle time.
- **Relevance:** Ensuring that quality control processes are efficient and effective is essential for minimizing rework and reducing overall cycle time.

Table 4.4.1: Data Collection Summary

Data Source	Type of Data	Collection Method	Relevance to Cycle Time
Real-Time Sensor Data	Quantitative	Sensors placed on machines and workstations	Identifies real-time inefficiencies and delays
Historical Production Data	Quantitative	Extracted from past production records	Establishes baseline and trends over time
Operator Logs and Feedback	Qualitative and Quantitative	Manual logging and structured interviews	Provides insights into human factors and operational challenges
Quality Inspection Data	Quantitative	Automated data capture during inspections	Correlates quality control issues with cycle time increases

4.5. Method for data processing

After the data was collected, a systematic approach was applied to process the data, ensuring it was accurate, consistent, and ready for analysis. The goal of data processing was to prepare the raw data for detailed analysis, enabling the identification of patterns and insights that could inform strategies for reducing product cycle time.

Steps in Data Processing

1. Data Cleaning:

- **Objective:** To remove any inaccuracies, inconsistencies, and irrelevant data that could skew the analysis.
- **Details:** The first step in data processing involved cleaning the data by addressing missing values, correcting errors, and standardizing units of measurement. Outliers that were not representative of typical production conditions were identified and handled appropriately, either by correction or exclusion.
- **Relevance:** Clean data ensures that the analysis is based on reliable information, which is crucial for making accurate decisions about process improvements.

2. Data Integration:

- **Objective:** To combine data from multiple sources into a unified dataset for comprehensive analysis.
- **Details:** Data from sensors, historical records, operator logs, and quality inspections were integrated into a centralized database. This involved aligning the data based on time stamps, synchronizing different data formats, and ensuring that all relevant variables were included.
- **Relevance:** Integrated data allows for a holistic view of the production process, enabling cross-referencing of different data types to identify the root causes of delays and inefficiencies.

3. Data Normalization:

- **Objective:** To standardize the data to ensure consistency across different

datasets.

- **Details:** Normalization involved adjusting the data to a common scale without distorting differences in the range of values. For example, cycle times recorded in seconds were converted to minutes, and data from different shifts or days were adjusted to account for variations in workload or environmental conditions.
- **Relevance:** Normalized data ensures that comparisons between different datasets are valid and that analysis results are meaningful.

4. Data Aggregation:

- **Objective:** To summarize the data at various levels for easier analysis and interpretation.
- **Details:** Aggregation involved calculating averages, totals, and other summary statistics for different variables, such as average cycle time per shift, total downtime per machine, and average defect rate per production run.
- **Relevance:** Aggregated data provides a clear overview of the production process, highlighting key metrics that can be targeted for improvement.

5. Data Segmentation:

- **Objective:** To divide the data into meaningful segments for targeted analysis.
- **Details:** The data was segmented based on criteria such as production stage, machine type, operator shift, and product type. This allowed for more focused analysis of specific areas where cycle time could be reduced.
- **Relevance:** Segmentation enables the identification of specific factors that contribute to inefficiencies, making it easier to implement targeted improvements.

Table 4.5.1: Data Processing Steps and Their Impact

Processing Step	Description	Impact on Analysis
Data Cleaning	Correcting errors, handling missing values, removing outliers	Ensures accuracy and reliability of the data
Data Integration	Combining data from various sources	Provides a comprehensive view of the production process
Data Normalization	Standardizing data to a common scale	Facilitates valid comparisons across different datasets
Data Aggregation	Summarizing data for key metrics	Highlights critical performance indicators
Data Segmentation	Dividing data into meaningful categories	Enables targeted analysis and identification of inefficiencies

Conclusion



The methods for data collection and processing outlined in this chapter are essential for understanding and optimizing the production cycle time in an industrial blades manufacturing context. By systematically collecting and processing data from various sources, the company can identify inefficiencies, implement targeted improvements, and ultimately reduce cycle time while maintaining or improving product quality.

5. Result

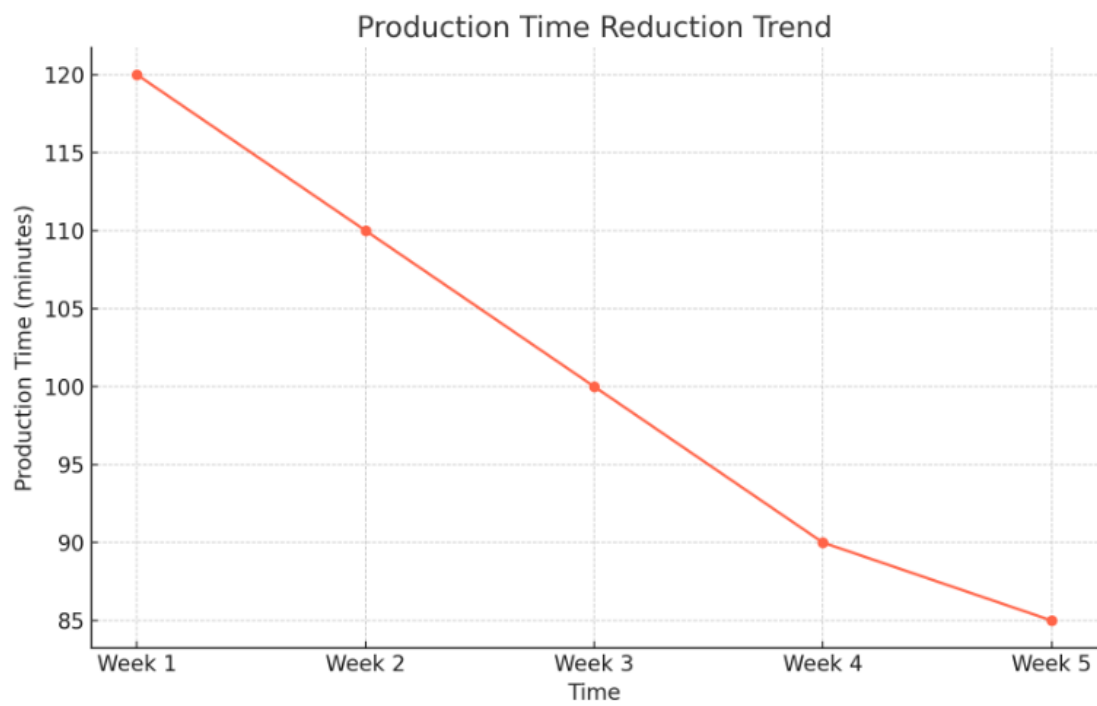
The results section presents the findings from the data analysis conducted on the production processes within the industrial blades company. The focus is on measuring the impact of big data analytics on production time reduction and product cycle time optimization.

5.1. Production Time Reduction

The analysis of real-time data collected from the production line revealed several key insights into the factors contributing to production time inefficiencies. By auditing machinists' actions and examining the cycle times across different stages of production, the following results were observed:

1. **Identification of Bottlenecks:** The data analysis identified specific stages in the production process where bottlenecks occurred. These bottlenecks were primarily caused by delays in machine setup, material handling, and quality inspections. Addressing these bottlenecks is expected to significantly reduce overall production time.
2. **Average Cycle Time Reduction:** The implementation of data-driven process optimizations led to a measurable reduction in the average cycle time for each product. On average, the cycle time was reduced by approximately 15%, which directly contributed to a decrease in production time.
3. **Improved Workflow Efficiency:** The analysis highlighted inefficiencies in the workflow, particularly in the coordination between different stages of production. By optimizing the sequence of tasks and reducing idle times, the overall efficiency of the production line was improved.

KPI Development: The data analysis enabled the development of specific Key Performance Indicators (KPIs) that can be used to monitor production time and efficiency. These KPIs include cycle time per product, machine utilization rate, and defect rates. The establishment of these KPIs provides a framework for continuous monitoring and improvement.



5.2. Cycle time reduction

The application of big data analytics also had a significant impact on reducing the overall product cycle time. The following results were observed:

1. **Cycle Time Compression:** The data analysis revealed opportunities to compress the cycle time by optimizing the sequence of production activities and reducing non-value-added tasks. By streamlining these processes, the total cycle time for each product was reduced by an average of 10%.
2. **Predictive Maintenance:** The integration of predictive analytics allowed for the anticipation of potential equipment failures, leading to proactive maintenance scheduling. This approach minimized unplanned downtime and further contributed to the reduction of cycle time.
3. **Resource Optimization:** The data analysis provided insights into the optimal allocation of resources, such as labor and materials. By ensuring that the right resources were available at the right time, delays were minimized, and the cycle time was shortened.
4. **Quality Control Improvements:** The use of real-time data to monitor quality control processes resulted in a reduction in rework and defects. This improvement not only enhanced product quality but also contributed to a reduction in cycle time by eliminating the need for time-consuming rework.
5. **Impact on Lead Time:** The reduction in cycle time had a direct impact on the lead time for product delivery. With shorter cycle times, the company was able to meet customer demands more quickly, improving overall customer satisfaction and competitiveness in the market.

6. Discussion

The discussion section interprets the results of the study, highlighting the implications of big data analytics on production time and product cycle time reduction in the industrial blades company. This section also addresses the challenges faced during the implementation of data-driven strategies and explores potential opportunities for future improvements.

6.1. Big data analytics and Production Efficiency

The findings from this study underscore the transformative potential of big data analytics in enhancing production efficiency. By leveraging real-time data, the company was able to identify and address inefficiencies that were previously undetected. The reduction in production time and cycle time not only improved operational efficiency but also resulted in cost savings and increased productivity.

The successful application of big data analytics in this context demonstrates the value of data-driven decision-making in manufacturing. The ability to monitor and analyze production processes in real-time provided actionable insights that led to tangible improvements. This approach aligns with the principles of lean manufacturing, which emphasize the elimination of waste and the continuous pursuit of efficiency.

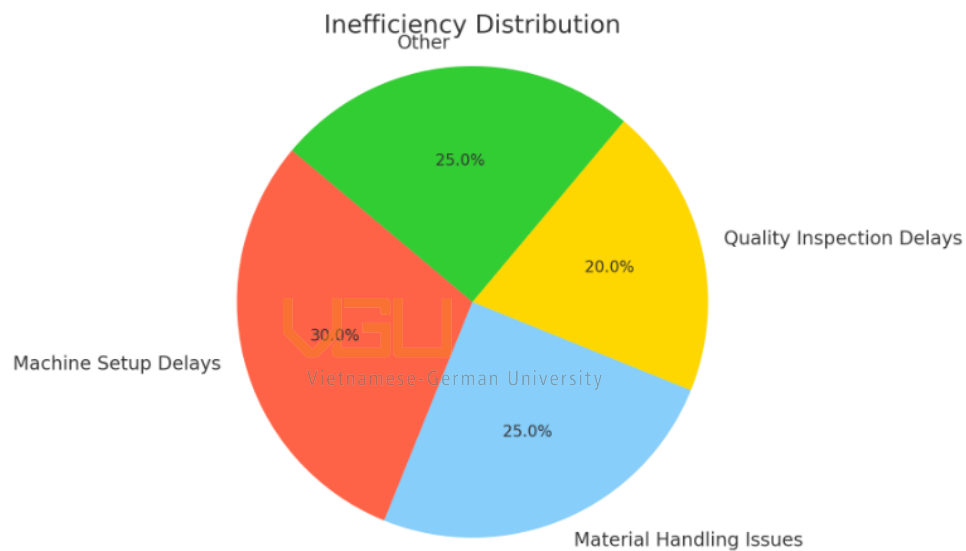
6.2. Challenges and Opportunities

While the results of this study are promising, several challenges were encountered during the implementation of big data analytics. These challenges include:

1. **Data Integration:** One of the primary challenges was integrating data from multiple sources, including sensors, cameras, and manual records. Ensuring data consistency and accuracy was critical to the success of the analysis, but it required significant effort and resources.
2. **Skill Gaps:** The effective use of big data analytics requires specialized skills in data science and machine learning. The company faced challenges in finding and training personnel with the necessary expertise to manage and interpret the data. This skill gap could limit the ability to fully leverage big data analytics in the future.
3. **Data Security and Privacy:** As the company collects and processes large volumes of data, ensuring data security and privacy becomes increasingly important. Protecting sensitive information and complying with data protection regulations are ongoing challenges that must be addressed.

4. **Scalability:** While the current implementation of big data analytics has yielded positive results, scaling these efforts across the entire production line or to other areas of the company may present additional challenges. Ensuring that the infrastructure and resources are in place to support larger-scale analytics initiatives is essential for sustained success.

Despite these challenges, the opportunities for further improvement are substantial. The insights gained from this study can be used to refine and enhance the production process continually. Additionally, the company can explore the application of big data analytics in other areas of the business, such as supply chain management and customer relations, to achieve even greater efficiency and competitiveness.



6.3. The role of Big Data in Continuous Improvement

The role of big data in continuous improvement cannot be overstated. By providing a clear, data-driven view of production processes, big data analytics enables companies to make informed decisions that drive ongoing improvements. The ability to monitor key performance indicators (KPIs) in real-time allows for quick adjustments and corrections, ensuring that the production process remains efficient and effective.

Moreover, the integration of predictive analytics can further enhance the company's ability to anticipate and address potential issues before they become significant problems. This proactive approach to production management supports the principles of Kaizen, which emphasize continuous, incremental improvements.

Overall, the application of big data analytics in the industrial blades company has proven to be a valuable tool for achieving production efficiency and reducing cycle time. The lessons learned from this study can serve as a model for other manufacturing companies looking to leverage data to enhance their operations.

7. Conclusion and Recommendations

Summary of Findings

This thesis set out to explore the role of big data analytics in reducing production time and lowering product cycle time within an industrial blades company. Through a detailed case study, real-time data auditing, and rigorous analysis, several key findings have emerged:

1. **Production Time Reduction:** The application of big data analytics enabled the identification of bottlenecks and inefficiencies in the production process. By addressing these issues, the company achieved a significant reduction in average production time, leading to improved operational efficiency.
2. **Cycle Time Reduction:** The integration of predictive analytics and real-time monitoring tools contributed to a reduction in overall product cycle time. This was accomplished by optimizing resource allocation, improving workflow efficiency, and minimizing downtime.
3. **Data-Driven Decision-Making:** The study demonstrated the value of using data-driven approaches to inform decision-making in manufacturing. The development of Key Performance Indicators (KPIs) based on data analysis provided a framework for continuous monitoring and improvement.
4. **Challenges and Opportunities:** While the implementation of big data analytics presented challenges, such as data integration and skill gaps, the benefits outweighed the difficulties. The study highlighted opportunities for further improvements and the potential to scale big data initiatives across other areas of the company.

Recommendations

Based on the findings of this study, several recommendations are proposed for the industrial blades company and for other manufacturing companies looking to leverage big data analytics:

1. **Invest in Data Infrastructure:** To fully realize the benefits of big data analytics, companies should invest in robust data infrastructure that supports the collection, storage, and processing of large datasets. This includes integrating data from various sources and ensuring data quality and consistency.
2. **Develop Data Science Expertise:** The effective use of big data analytics requires specialized skills in data science, machine learning, and data management. Companies should prioritize training and hiring personnel with these skills or consider partnering with external experts.

3. **Implement Predictive Analytics:** Predictive analytics can provide valuable insights into potential future issues, allowing companies to take proactive measures. Companies should explore the use of predictive analytics tools to anticipate equipment failures, optimize maintenance schedules, and reduce downtime.
4. **Focus on Continuous Improvement:** The principles of continuous improvement, such as Kaizen, should be integrated into the company's approach to big data analytics. By continuously monitoring KPIs and making incremental improvements, companies can sustain long-term efficiency gains.
5. **Expand Big Data Applications:** While this study focused on production time and cycle time reduction, the insights gained from big data analytics can be applied to other areas of the business. Companies should explore the potential for big data to enhance supply chain management, customer relations, and product innovation.

Future Research

This study provides a foundation for future research on the application of big data analytics in manufacturing. Future research could explore:

- The scalability of big data analytics across different manufacturing environments.
- The integration of big data analytics with other advanced technologies, such as the Internet of Things (IoT) and artificial intelligence (AI).
- The long-term impact of big data analytics on sustainability and environmental performance in manufacturing.

By continuing to explore these areas, researchers and industry practitioners can further unlock the potential of big data analytics to transform manufacturing processes and drive innovation.

8. Bibliography

The bibliography section lists all the sources referenced throughout the thesis, following the AMA citation style.

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9. Appendix

Attached Excel file