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REDUCTION OF PRODUCTION/PROCESSING TIME IN THE MANUFACTURING SECTOR THROUGH THE APPLICATION OF PROJECT MANAGEMENT TECHNIQUES

CHAPTER ONE

INTRODUCTION

1.0 Background to the Study

The manufacturing sector remains the biggest economic development and industrialization driver, contributing significantly to GDP, employment, and technological advancement globally (Naudé & Szirmai, 2012). In 2022, the manufacturing sector added a significant 2.79 trillion U.S. dollars to the GDP of the United States. Compared to the global economic landscape, only seven countries- China, Japan, Germany, India, the United Kingdom, France, and the United States— surpass the U.S. manufacturing sector in GDP contributions. However, the sector often faces persistent challenges, including inefficiencies in production and processing times, which can lead to increased costs, reduced competitiveness, and lower profitability (Quiroz-Flores, & Vega-Alvites,, 2022). The application of project management techniques offers a viable solution to these challenges, potentially transforming production processes through improved planning, execution, and control mechanisms.

Over the years, various companies within the manufacturing industry have used project management to monitor their production activities and oversee specific projects they embark upon (Pozzi et al., 2023). These projects may be the improvement or optimization of their sophisticated machinery, the enhancement of their production line efficiency, updating existing processes or technologies used for production or establishment a new production plant. The result of this is the improvement and optimized performance of the manufacturing output of the company, and this manufacturing efficiency is paramount for maintaining competitive advantage in a globalized market (Palange & Dhatrack, 2021).

However, Achieng (2021) posited that despite advancements in technology and automation, the average production cycle time in manufacturing has not significantly decreased over the past decade, underscoring a critical area for improvement. This stagnation can be attributed to several factors, including inadequate implementation of advanced methodologies, resistance to change, and the complexity of integrating new processes into existing systems (Schemel, 2021). Moreover, inefficiencies often arise from poor planning, inadequate resource allocation, and suboptimal execution strategies, which inflate production costs and extend lead times, thereby affecting the overall supply chain performance (Khan et al., 2022).

A pertinent example is Toyota, a company renowned for its Lean manufacturing system, which has set global benchmarks for efficiency and productivity. Toyota's Lean manufacturing system, often referred to as the Toyota Production System (TPS), has long stood as a paradigm of efficiency and operational excellence within the manufacturing sector. At its core, TPS is dedicated to the relentless elimination of waste, the enhancement of product flow, and the continuous improvement of overall quality. This philosophy, deeply rooted in the Japanese concept of Kaizen, promotes ongoing, incremental improvements across all facets of the production process. By rigorously identifying and eliminating non-value-adding activities, Toyota has managed to

significantly streamline its operations. This meticulous focus on waste reduction allows the company to maintain exceptionally low inventory levels, adhering to just-in-time principles that ensure materials and components are available precisely when needed, thereby minimizing storage costs and reducing the risk of excess inventory.
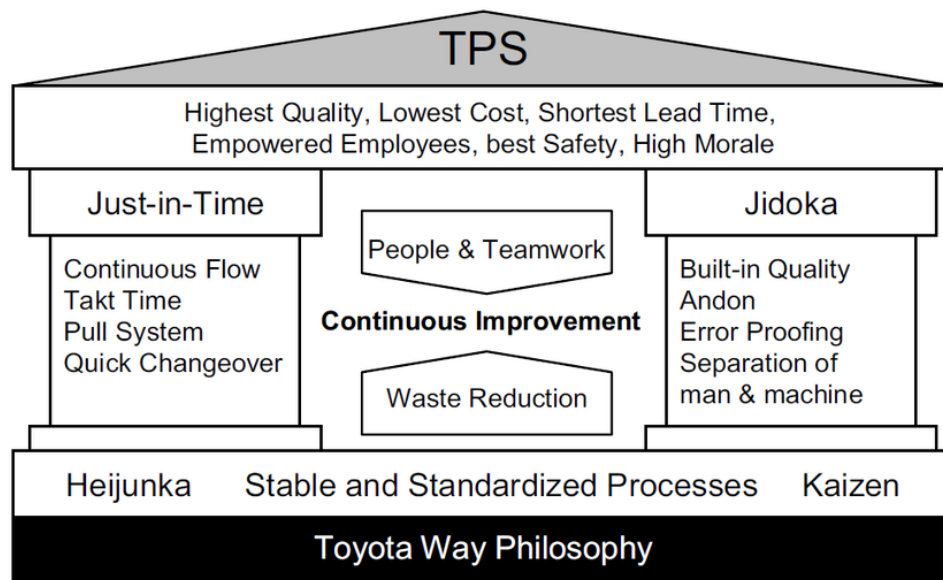

Fig 1: The core principle of the Toyota Production System (Herrmann et al, 2008)

However, the challenges Toyota faced during the Tohoku earthquake underscore the critical importance of vigorous project management techniques in the manufacturing sector (Liker & Convis, 2012). While Lean principles excel in optimizing routine operations by eliminating waste and streamlining processes, they alone may not suffice in addressing extraordinary disruptions. Project management techniques offer a comprehensive strategic framework that goes beyond day-to-day efficiency improvements (Kerzner, 2013). These techniques encompass detailed risk management practices that identify potential threats and vulnerabilities within the supply chain, allowing companies to develop proactive mitigation strategies (Project Management Institute, 2017). Furthermore, project management methodologies emphasize contingency planning, which prepares organizations for unforeseen events by establishing predefined action plans and resource allocations (Hillson & Simon, 2012). In the event of a disruption, such as the Tohoku earthquake, these plans facilitate a structured and swift response, minimizing downtime and mitigating impacts on production. Additionally, project management fosters enhanced coordination and communication across all levels of the organization, ensuring that critical information flows seamlessly and timely decisions are made (Kerzner, 2013). By integrating these techniques with Lean principles, manufacturing firms can achieve operational efficiency, resilience, and agility, enabling them to maintain stability and competitiveness even in the face of significant disruptions

(Liker & Convis, 2012). Adopting Agile project management techniques could have improved Toyota's ability to adapt to the rapidly changing circumstances following the earthquake. Agile methodologies promote flexibility, iterative planning, and swift decision-making, allowing teams to pivot and implement alternative strategies as needed. This adaptability would have been crucial in minimizing downtime and resuming production more quickly (Schwaber & Sutherland, 2017).

The implementation of project management techniques in the manufacturing sector has become increasingly critical and important as industries strive to enhance efficiency, reduce costs, and improve product quality (Pozzi et al., 2023). Project management provides a structured framework that ensures systematic planning, execution, and control of production processes. Efficient implementation of these project management techniques helps meet deadlines and budget constraints and plays a vital role in risk management and resource optimization (Hindarto, 2023). Project management techniques, encompassing methodologies such as Lean Manufacturing, Six Sigma, Agile, and Critical Path Method (CPM), have demonstrated the potential to enhance efficiency and reduce production times (Stern, 2020).

1.1 Problem Statement

Over the years, the manufacturing sector has faced significant challenges in reducing production and processing times. Despite advancements in technology and management practices, many manufacturers continue to struggle with various obstacles and inefficiencies that unnecessarily prolong their production time, which in turn negatively affects their competitiveness and profitability (Koren, 2010). This inefficiency is partly a result of the underutilization of effective project management techniques that have proven successful in other industries, such as software development and services (Kerzner, 2013). For instance, the automotive industry, specifically in the United States, is under immense pressure to improve operational efficiency as a result of intense global competition and stringent regulatory requirements. These pressures are compounded by the cyclical nature of the industry, where peaks and troughs in demand often do not align with economic conditions (Womack et al., 2007). This misalignment results in substantial financial strain on manufacturers, necessitating a more agile and responsive approach to production management (Cusumano, 2010).

Traditional manufacturing strategies often focus on maximizing production capacity and meeting regulatory standards but fail to address the critical need for reducing lead times and enhancing overall productivity. As a result, manufacturers experience increased costs, longer time-to-market, and reduced ability to respond to market changes swiftly (Monden, 2011). The adoption of project management techniques tailored to the unique needs of the manufacturing sector presents a promising solution to these issues.

Project management techniques, such as Agile, Lean, and Six Sigma, have demonstrated success in other industries by enhancing process efficiency, improving quality, and reducing waste (George et al., 2005). However, their application in the manufacturing sector remains limited. Implementing these techniques can potentially streamline production processes, reduce

bottlenecks, and optimize resource utilization, thereby significantly reducing production and processing times (Antony, 2006).

The problem, therefore, is the persistent inefficiency in production and processing times within the manufacturing sector, primarily due to the inadequate application of project management techniques. This inefficiency not only impacts the operational effectiveness of manufacturers but also their competitive edge in the global market (Flynn et al., 1995). There is a critical need for a comprehensive study to explore how project management techniques can be effectively adapted and applied to the manufacturing sector to address these inefficiencies (Kerzner, 2013).

This research aims to fill the gap by investigating the potential of project management techniques in reducing production and processing times in the manufacturing industry. By identifying best practices and developing a framework for their implementation, the study seeks to provide manufacturers with practical solutions to enhance their operational efficiency and competitiveness (Cusumano, 2010).

1.2 Study Purpose

The purpose of this study is to critically examine how the application of project management techniques can significantly reduce production and processing times in the manufacturing sector. Despite technological advancements and the adoption of various efficiency models, the manufacturing industry continues to grapple with persistent inefficiencies that impede optimal productivity. This study aims to identify the underlying causes of these inefficiencies and assess the potential of project management methodologies to address them effectively.

Manufacturing has historically been a cornerstone of economic development, yet it is plagued by challenges such as poor resource allocation, inadequate planning, and suboptimal execution strategies. These issues contribute to prolonged production cycles, increased operational costs, and reduced competitiveness on a global scale. Traditional efficiency models like Lean Manufacturing and Six Sigma have provided substantial improvements; however, they often fall short in the face of complex, unforeseen disruptions. The study will critically analyze these limitations and explore how project management techniques can fill the gaps left by these traditional models.

Project management techniques encompass a range of methodologies, including Agile, Critical Path Method (CPM), and Earned Value Management (EVM), each offering unique tools for improving planning, execution, and control of manufacturing processes. This study will evaluate the effectiveness of these techniques in streamlining operations, enhancing flexibility, and improving response times to disruptions. By critically analyzing case studies of manufacturing firms that have successfully implemented these techniques, the study will extract valuable insights and best practices that can be generalized across the industry.

Furthermore, the study will address the barriers to implementing project management techniques in the manufacturing sector. Resistance to change, cultural inertia, and the complexity of integrating new methodologies into existing systems are significant challenges that need to be

overcome. By providing a critical examination of these barriers, the study aims to develop actionable recommendations for manufacturing firms seeking to enhance their operational efficiency through project management.

Lastly, the study will assess the long-term sustainability of efficiency improvements achieved through project management techniques. It will explore whether these improvements can be maintained over time and how they impact the overall resilience and adaptability of manufacturing operations in the face of future challenges. By taking a comprehensive and critical approach, this study intends to contribute valuable knowledge to the field of manufacturing and provide a strategic framework for companies aiming to reduce production and processing times through the effective application of project management techniques.

1.3 Study Aim, Research Objectives and Research Questions

This study aims to investigate the application of project management techniques to reduce production and processing times in the manufacturing sector, thereby enhancing overall efficiency and competitiveness. Hence the objectives of the study are;

i.3.1 Research Objectives

i. Identify common production inefficiencies in the manufacturing sector;

ii. assess the Impact of Project Management Techniques on Production Cycle Time in the Manufacturing Sector;

iii. assess the long-term sustainability of efficiency improvements achieved through project management techniques

iv. Develop Context-Specific Recommendations for the Application of Project Management Techniques in Various Manufacturing Environments;

1.3.2 Research Questions

i. What are the common production inefficiencies in the manufacturing industry

ii. How do various project management techniques, such as Lean, Six Sigma, and Agile, influence the production cycle time in manufacturing operations?

iii. How sustainable are the efficiency improvements achieved through project management techniques over the long term in manufacturing operations?

iv. How sustainable are the efficiency improvements achieved through the application of project management techniques in the long term?

v. What are the best practices and customization strategies for applying project management techniques in different types of manufacturing operations?

CHAPTER TWO
LITERATURE REVIEW

2.0 Introduction

The manufacturing sector is a critical driver of economic growth, innovation, and employment globally. However, it faces persistent challenges related to inefficiencies in production and processing times. These inefficiencies can result in increased costs, reduced competitiveness, and

lower profitability. The application of project management techniques offers a promising avenue to address these challenges by providing structured approaches to planning, execution, and control. This chapter reviews the existing literature on production inefficiencies in the manufacturing sector and the effectiveness of various project management methodologies in mitigating these inefficiencies. It explores foundational theories and models, including Lean Manufacturing, Six Sigma, Agile, and Critical Path Method (CPM), and assesses their impact on reducing production times. Additionally, the review examines case studies of manufacturing firms that have successfully implemented these techniques, highlighting best practices and common pitfalls. By synthesizing current research, this chapter aims to provide a comprehensive understanding of how project management techniques can enhance efficiency and productivity in manufacturing. The insights gained from this literature review will form the basis for developing a framework to guide the effective application of project management techniques in the manufacturing sector.

2.2 Production Inefficiencies in The Manufacturing Sector

The manufacturing sector, while being a pivotal contributor to global economic growth, faces significant inefficiencies that impede optimal performance. This section critically reviews the literature on production inefficiencies in the manufacturing sector, examining various dimensions such as resource allocation, process optimization, and the integration of advanced methodologies. It highlights the critical gaps and proposes potential areas for future research.

Effective resource allocation is fundamental to manufacturing efficiency, yet numerous studies highlight persistent challenges in this area. According to Khan et al. (2022), misallocation of resources often leads to bottlenecks, underutilization of capacity, and increased operational costs. For instance, the over-reliance on manual processes without adequate investment in automation technologies is a recurrent issue (Khan et al., 2022). This is prevalent in small-scale manufacturing firms, as they often struggle with high labor costs and low productivity due to their dependence on manual labor. This reliance leads to increased error rates, inconsistent product quality, and inefficiencies that hinder scalability and competitiveness in the global market. Consequently, these firms face significant operational challenges that could be mitigated through strategic investments in automation technologies (Kusiak, 2018). Without such investments, they remain at a disadvantage compared to automated counterparts. Furthermore, inadequate training and development of the workforce can result in suboptimal use of advanced machinery and technologies, exacerbating inefficiencies (Kumar & Parashar, 2015).

The optimization of manufacturing processes is crucial for reducing production times and costs. Lean Manufacturing and Six Sigma are widely adopted methodologies aimed at process improvement. However, Herrmann et al. (2008) argue that while Lean principles are effective in waste reduction, they often fail to address variability and complexity in production processes. Similarly, Six Sigma focuses on reducing defects but may not be flexible enough to adapt to rapid market changes (Antony, 2004). These methodologies require substantial cultural and

organizational changes, which are often met with resistance, further complicating their effective implementation (Henderson & Evans, 2000).

The integration of advanced technologies such as IoT, AI, and robotics holds promise for addressing inefficiencies. However, the transition from traditional manufacturing systems to smart manufacturing is fraught with challenges. According to Pozzi et al. (2023), the high cost of technology adoption, coupled with a lack of skilled personnel, hampers the widespread implementation of these innovations. Additionally, the literature points to the issue of interoperability between new technologies and existing systems, which can lead to significant downtime and increased complexity in managing production processes (Kusiak, 2018).

Real-world applications and case studies provide valuable insights into the practical challenges of reducing production inefficiencies. Toyota's Lean manufacturing system, despite its successes, faced significant setbacks during the 2011 Tohoku earthquake, which revealed vulnerabilities in its just-in-time inventory approach (Norio et al., 2013). This case underscores the need for robust risk management and contingency planning, which are often overlooked in efficiency-driven methodologies. Similarly, studies on other manufacturing firms highlight the importance of balancing efficiency with resilience to external shocks (Schemel, 2021).

Various literatures consistently identify several barriers to the effective implementation of efficiency-enhancing methodologies. Resistance to change is one of the major obstacle, often rooted in organizational culture and lack of management support (Achieng, 2021). Additionally, the complexity of integrating new processes and technologies into existing workflows can lead to significant disruptions and reduced productivity in the short term (Hindarto, 2023). Overcoming these barriers requires a holistic approach that includes strategic planning, stakeholder engagement, and continuous training and development.

2.1 Lean Manufacturing

Lean Manufacturing, a methodology originating from the Toyota Production System (TPS), has gained significant traction in the manufacturing industry as a means to enhance operational efficiency and eliminate waste (Pawlik et al., 2021). The core principle of Lean Manufacturing revolves around the continuous improvement process, waste reduction, quality enhancement, and the creation of value for customers by streamlining manufacturing processes (Bashar & Hasin, 2019). By focusing on eliminating non-value-added activities and optimizing production processes, Lean Manufacturing aims to enhance productivity, reduce costs, and improve overall performance (Kumar et al., 2022). According to Leksic et al., (2020), Lean Manufacturing focuses on waste elimination and process optimization, directly impacting production timelines. By advocating for continuous improvement and the elimination of non-value-added activities, lean principles can significantly reduce cycle times and improve throughput.
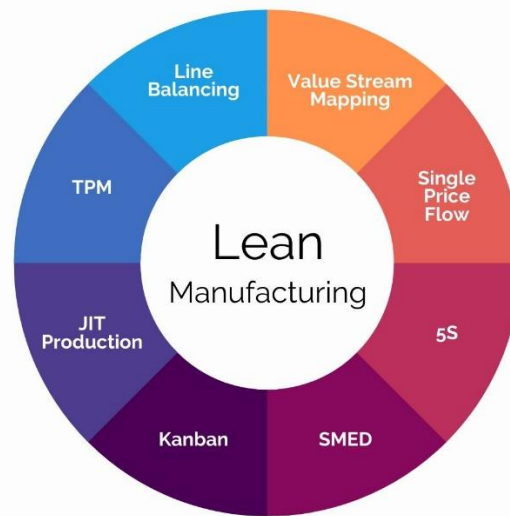
Fig 2: Lean Manufacturing

Techniques such as value stream mapping would be very important in identifying inefficiencies, while tools like 5S and Kanban would significantly streamline workflow and inventory management, leading to a significant cut in production time (Wang et al., 2024). Lean manufacturing also emphasizes employee involvement and systematic problem-solving to enhance productivity and quality (Harnandez-Matias et al., 2020). This holistic approach not only shortens production cycles but also increases overall operational efficiency, leading to cost savings and greater customer satisfaction. Implementing lean strategies allows manufacturers to respond more agilely to market demands and technological advancements, fostering a culture of constant enhancement (Javaid et al., 2022).

Numerous studies have highlighted the benefits of implementing Lean Manufacturing practices across various industries. Research has shown that Lean Manufacturing facilitates quality improvement, productivity enhancement, and cost reduction in companies that adopt its principles (Khalfallah & Lakhal, 2020). Additionally, the integration of Lean Manufacturing with other methodologies such as Agile Manufacturing has been found to further enhance operational and financial performance (Romero et al., 2019). This integration underscores the interconnectedness of different manufacturing practices and the potential synergies that can be achieved by combining them effectively. One of the key aspects of Lean Manufacturing is the identification and elimination of waste throughout the production process. This systematic approach to waste reduction is essential for creating value efficiently and meeting customer demands (Ramadas & Satish, 2021). Lean Manufacturing emphasizes the importance of continuous improvement and the removal of inefficiencies to optimize production systems (Romero et al., 2019). By focusing on activities that add value and minimizing those that do not, companies can enhance their competitiveness and sustainability in the market (Elnadi & Shehab, 2021).

Moreover, Lean Manufacturing is not limited to the shop floor but extends to various industries beyond traditional manufacturing sectors. From primary metals to aerospace businesses, the principles of Lean Manufacturing have been successfully applied to improve operational efficiency and drive performance excellence (Hines et al., 2004). This broad applicability underscores the versatility and effectiveness of Lean Manufacturing as a methodology for achieving operational excellence in diverse organizational settings.

In the context of small and medium-scale enterprises (SMEs), the implementation of Lean Manufacturing may face challenges related to employee barriers and resistance to change. Understanding and addressing these barriers are crucial for successful Lean Manufacturing adoption within SMEs (Ramadas & Satish, 2018). Creating a Lean culture within organizations is essential for the successful implementation of Lean Manufacturing practices and ensuring sustained improvements in operational performance (Aripin et al., 2023). By fostering a culture of continuous improvement and employee engagement, companies can overcome obstacles and drive successful Lean Manufacturing initiatives. Furthermore, Lean Manufacturing is not a static concept but continues to evolve in response to changing industry landscapes and technological advancements. The integration of Lean Manufacturing with emerging technologies such as Industry 4.0 and cyber-physical systems presents new opportunities for waste identification and elimination in the digital manufacturing world (Romero et al., 2019). By leveraging these technologies, companies can enhance their Lean Manufacturing practices and achieve greater efficiency in production processes.

2.2 Agile Project Management

Agile project management is a methodology that emphasizes flexibility and adaptability in project execution by promoting increased collaboration and communication among project stakeholders (Zasa et al., 2021). This approach aims to prevent large-scale project failures by enabling iterative development processes that allow for continuous feedback and adjustments throughout the project lifecycle (Mergel et al., 2021). By breaking down complex projects into smaller, manageable tasks, Agile project management facilitates the delivery of incremental value to stakeholders through rapid iterations (Ebirim *et al.*, 2024).

Agile methodologies facilitate adaptive planning and continuous improvement, which are essential for effectively responding to the ever-changing market demands and technological advancements. The iterative approach inherent in Agile allows manufacturers to quickly pivot and make necessary adjustments in real-time, reducing downtime and enhancing overall efficiency. This adaptability is particularly beneficial in a manufacturing environment where delays and inefficiencies can significantly impact productivity and costs. According to Amajuoyi et al., (2024), by breaking down projects into smaller, manageable increments, Agile enables frequent reassessment and optimization of processes, fostering a culture of constant improvement. This continuous feedback loop not only accelerates the production cycle but also improves product quality, ensuring that manufacturers can meet customer demands more swiftly and effectively. Thus, the integration of

Agile methodologies into manufacturing operations represents a strategic advantage in maintaining competitiveness and operational excellence (Varl et al., 2020).

One of the key aspects of Agile project management is its ability to foster creativity within project teams. Research has shown that Agile methodologies provide conducive environments for creativity by promoting collaboration, flexibility, and a focus on delivering value to customers (Olszewski, 2023). Additionally, Agile project management has been found to drive innovation in various industries, such as energy-efficient HVAC solutions, by prioritizing iterative development and quick response to changing requirements (Ebirim *et al.*, 2024). While Agile project management offers numerous benefits, it also presents challenges, particularly in large enterprises where scaling Agile practices can lead to shifts in project management approaches and team dynamics (Sońta-Drączkowska, 2024). The role of the project manager in Agile software teams has been a subject of study, with research aiming to clarify ambiguities and questions surrounding the responsibilities and contributions of project managers in Agile environments (Gandomani et al., 2020). It is essential for project managers to adapt to the Agile methodology, which requires a different set of skills and approaches compared to traditional project management practices.

Risk management is another critical aspect of Agile project management. While Agile methods are known for their flexibility and adaptability, they also introduce risks such as scope creep, timeline issues, and budget constraints (Elkhatib et al., 2022). Effective risk management in Agile projects involves identifying and addressing potential risks early on to ensure project success and customer satisfaction (Thom-Manuel, 2022). By integrating risk management practices into Agile software development projects, teams can mitigate uncertainties and improve project outcomes. The transition from traditional project management approaches to Agile methodologies requires careful consideration and planning. Organizations implementing Agile project management must focus on stakeholder engagement, collaboration, and flexibility to successfully adopt Agile practices (Pinto, 2023). Moreover, the integration of Agile methods with established project management frameworks like PMBOK can enhance project management practices by combining the strengths of both approaches (Silva, 2023).

In the context of project governance, middle managers play a crucial role in ensuring the success of Agile software development projects (Uwadi *et al.*, 2022). Their involvement in project governance activities helps maintain alignment with organizational goals, facilitate communication among team members, and address challenges that may arise during project execution. Additionally, Agile methodologies provide a framework for project management tasks that enable teams to be flexible, responsive to change, and deliver results iteratively (Miller, 2019). Overall, Agile project management has become increasingly popular across various industries due to its emphasis on collaboration, flexibility, and iterative development. By embracing Agile methodologies, organizations can enhance creativity, drive innovation, and improve project outcomes through effective risk management and stakeholder engagement. However, successful implementation of Agile project management requires a shift in mindset, adoption of new

practices, and continuous improvement to adapt to changing project requirements and stakeholder needs.

2.3 Six Sigma

Six Sigma employs statistical tools to identify and eliminate defects, thereby streamlining processes and reducing time wastage (Duc & Thu, 2022). This project management technique focuses on process variability and aims for near-perfection, which leads to substantial improvements in production efficiency and quality. The methodology's core principles, Define, Measure, Analyze, Improve, and Control (DMAIC), systematically address inefficiencies and root causes of defects (Nandakumar et al., 2020). This structured approach ensures that variations are minimized, resulting in more consistent and predictable production outcomes. By reducing variability and defects, Six Sigma not only enhances product quality but also significantly shortens processing times. Implementing Six Sigma in manufacturing helps in achieving higher levels of customer satisfaction, cost savings, and competitive advantage (Madhani, 2020). The emphasis on data-driven decision-making and continuous improvement fosters a culture of excellence and operational efficiency, ultimately driving better business performance.

One key advantage of Six Sigma is its ability to utilize statistical tools to identify process issues accurately and demonstrate improvements using objective data (Feng & Manuel, 2008). This data-driven approach is crucial in healthcare, where precision and quality are paramount. Moreover, the literature review by Utomo (2020) focuses on the implementation of Six Sigma in service industries, offering insights into how this methodology can be applied beyond manufacturing sectors. This broadening of Six Sigma's scope to service industries, including healthcare, highlights its versatility and effectiveness in diverse settings. The study specifically addresses the use of Six Sigma to reduce errors in healthcare payer firms, showcasing its potential in addressing specific challenges within the healthcare sector (M & Kunnath, 2019).

Various studies have highlighted the successful application of Six Sigma in different manufacturing sectors such as ceramic, paper, gems and jewellery, cement, furniture, and forging industries (Patel & Desai, 2018). The methodology has been utilized to address specific issues like reducing failure rates in high voltage testing of insulators (Desai & Shaikh, 2018), improving grinding processes (Noori & Latifi, 2018), and preventing industrial accidents (Ray et al., 2011). Additionally, Six Sigma has been instrumental in reducing oil leakage in heavy-duty transformers Neeru et al. (2023) and enhancing the effectiveness of training and development in the pharmaceutical industry (Chakraborty and Pant, 2024). Lean Six Sigma, a combination of Lean Manufacturing and Six Sigma, has also gained prominence in the manufacturing sector for driving sustainable practices and improving environmental performance (Huang et al., 2023). Studies have shown that Lean Six Sigma principles, data-driven decision-making, and a positive company culture contribute to enhancing sustainability while maintaining competitiveness (Huang et al., 2023). Furthermore, the integration of Lean Manufacturing and Six Sigma has been effective in

continuous improvement initiatives in industries and services (Silva, Oliveira and Magalhães, 2023).

The success factors for implementing Six Sigma in the manufacturing industry have been identified as leadership and strategy, focus on market and customer, evaluation and motivation, and project management (Yi-zhong *et al.*, 2008). These critical success factors play a significant role in the effective implementation of Six Sigma methodologies in manufacturing enterprises. Moreover, the application of Six Sigma has been associated with reducing defects, increasing sigma levels, and improving overall performance in industries like the pharmaceutical sector (Alkunsol *et al.*, 2019).

2.4 Critical Path Method (CPM)

The Critical Path Method (CPM) provides a structured approach to project scheduling, identifying the longest sequence of tasks that must be completed on time for the entire project to be finished on schedule (Suryono & Hasbullah, 2020). By focusing on critical tasks and managing dependencies effectively, CPM helps minimise delays and optimise resource utilization (Taghipour et al., 2020). This method ensures that resources are allocated efficiently to critical tasks, preventing bottlenecks and reducing production cycle times. By clearly outlining task sequences and timelines, CPM facilitates better coordination and communication among team members, leading to more streamlined operations (Khandekar, 2020). The emphasis on critical tasks ensures that any potential delays are promptly addressed, maintaining project momentum and ensuring timely project completion.

The Critical Path Method (CPM) is a widely recognized deterministic scheduling technique extensively used in various industries, particularly in project management and construction scheduling (Fadjar, Ali and Setiawan, 2023). CPM aids in identifying the critical path, which is crucial for determining the sequence of activities that dictate the minimum project duration (Pankaj, Kumar and Agarwal, 2020). By focusing on the critical path, project managers can streamline activities to accelerate project completion and mitigate delays (Ali, Tjendani and Witjaksana, 2024). CPM is instrumental in estimating project duration, assessing scheduling flexibility, and optimizing project timelines (Wulandari, Dachyar and Farizal, 2018). It is a fundamental tool for project planning, controlling, and monitoring, ensuring efficient resource utilization and workflow management (Olivieri, Seppänen and Denis Granja, 2018).

Moreover, CPM is often used in conjunction with the Project Evaluation and Review Technique (PERT) to enhance project success probability and identify critical tasks (Hana and Tjendani, 2022). The integration of CPM and PERT allows for a comprehensive analysis of project timelines and critical activities, aiding in effective project acceleration strategies (Hana and Tjendani, 2022). Additionally, CPM has been a cornerstone in construction project scheduling since its inception in the 1950s, highlighting its enduring relevance and effectiveness in time management and project scheduling (Ökmen, Bosch-Rekveldt and Bakker, 2022). While CPM is a robust scheduling method, criticisms have been raised regarding its deterministic nature, which overlooks

uncertainties inherent in project schedules (Ock and Han, 2010). Despite this critique, CPM remains a prevalent and valuable tool in project management, offering a structured approach to project planning and control (Simion *et al.*, 2019).

Common production inefficiencies in the manufacturing sector

Common production inefficiencies in the manufacturing sector can stem from various challenges that the industry faces. These challenges include issues related to workforce education (Daum *et al.*, 2024), complexity in manufacturing systems (Huah, Mahmood and Rahman, 2018), managing product variety and customization (Andersen *et al.*, 2018), and the need for flexibility in production processes (Wan et al., 2021). Additionally, challenges such as inadequate process control and material handling in ultra-precision manufacturing (Adeleke, 2024), the limitations of traditional manufacturing technologies for large-scale production (Lee et al., 2020), and the low production rates of additive manufacturing compared to traditional processes contribute to inefficiencies (Coatanéa *et al.*, 2021).

Moreover, the industry grapples with challenges related to the adoption of new technologies like 3D printing (Shahrubudin et al., 2020), the need for continuous development of products and processes to meet customer expectations (Helman, 2022), and the impact of globalization on manufacturing environments (Ariafar et al., 2012). Furthermore, issues such as the high complexity in Engineer-To-Order operations (Strandhagen et al., 2019), regulatory challenges in the production of cell therapies (Hourd, 2014), and the barriers to digital transformation in manufacturing firms Ahmad et al. (2022) add to the inefficiencies faced by manufacturers.

To address these inefficiencies, manufacturers must focus on optimizing processes for cell therapy manufacturing (Fritsche et al., 2020), leveraging reinforcement learning for sustainable and lean production (Paraschos, 2024), and developing strategies for thriving in local manufacturing contexts (Koren et al., 2017). Additionally, the adoption of technologies like reconfigurable manufacturing systems, artificial intelligence-driven customized manufacturing factories, and digital twins for manufacturing processes support can enhance efficiency and address production challenges.

Project Management Techniques and Production Cycle Time in the Manufacturing Sector

Project management techniques play a crucial role in the manufacturing sector by influencing production cycle time. Effective project management can lead to streamlined processes, improved resource allocation, and enhanced coordination, ultimately reducing cycle times and increasing efficiency. Several key factors impact the production cycle time in manufacturing, and project management techniques can address these factors to optimize operations. One significant aspect influenced by project management techniques is the planning and scheduling of manufacturing processes. Proper project planning ensures that tasks are sequenced efficiently, resources are allocated effectively, and potential bottlenecks are identified and mitigated Irfan et al. (2021). By utilizing tools like the Work Breakdown Structure (WBS) matrix and techniques such as the

Critical Path Method (CPM) and Project Evaluation Review Technique (PERT), project managers can break down complex projects into manageable tasks, set realistic timelines, and identify critical activities that directly impact cycle time (Sutrisna et al., 2018; Bagshaw, 2021).

Moreover, project management plays a vital role in resource management within manufacturing operations. Efficient allocation of resources, including materials, equipment, and manpower, is essential for optimizing production cycle times. Project managers can use advanced inventory management techniques, demand forecasting, and production planning processes to ensure that resources are utilized effectively and that production processes run smoothly (Yeshwanth & Bhavana, 2022; Dey, 2002). Additionally, talent management practices and transformational leadership can enhance employee performance and innovative work behavior, further contributing to improved production cycle times (Sayyam et al., 2020). Quality management practices also intersect with project management in the manufacturing sector. The implementation of quality practices not only ensures product quality but also impacts production efficiency. The adoption of Total Quality Management (TQM) principles can lead to continuous process improvement, waste reduction, and enhanced overall organizational performance (Zwikael & Globerson, 2007). By integrating quality management into project management processes, manufacturers can achieve higher levels of efficiency and reduce cycle times.

Furthermore, the application of digital transformation in project and capture management can drive sustainable growth in manufacturing SMEs by enabling real-time monitoring, data-driven decision-making, and improved collaboration among team members (Awonuga, 2024). The integration of big data analytics can further enhance project performance by providing valuable insights, predicting potential risks, and optimizing project outcomes (Mangla et al., 2020). In conclusion, project management techniques have a profound impact on production cycle times in the manufacturing sector. By leveraging tools and methodologies such as project planning, resource management, quality practices, and digital transformation, manufacturers can streamline operations, reduce inefficiencies, and ultimately improve production cycle times. Effective project management not only enhances operational efficiency but also contributes to overall business success and competitiveness in the dynamic manufacturing landscape.

Key Factors Influencing the Successful Implementation of Project Management Practices in Manufacturing

The successful implementation of project management practices in the manufacturing sector is influenced by various key factors that play a critical role in ensuring project success. These factors encompass a wide range of aspects, including leadership competencies, project planning and control, risk management, human factors, and external environmental considerations. By understanding and addressing these factors, manufacturing companies can enhance their project management capabilities and improve overall operational efficiency. One of the fundamental factors influencing the successful implementation of project management practices in manufacturing is the leadership competencies of project managers. Research has shown that inner

confidence, self-belief, and effective leadership skills are essential for project managers to deliver projects successfully Geoghegan & Dulewicz (2008). Strong leadership can inspire teams, drive project progress, and navigate challenges effectively, ultimately contributing to project success.

Effective project planning and control are also critical factors that impact the successful implementation of project management practices in manufacturing. Factors such as project-related considerations, project procedures, project management actions, and human-related factors all play a role in shaping the success of project planning and control processes (Li et al., 2018). By establishing clear project goals, defining project procedures, and implementing robust project management actions, manufacturing companies can enhance project planning and control efficiency. Moreover, the integration of risk management practices into project management processes can significantly influence project success in the manufacturing sector. Managing project risks, particularly in complex manufacturing projects such as the development of new car models, can lead to improved project management performance and overall project success (Fernando et al., 2018). By identifying and mitigating risks proactively, companies can minimize disruptions, optimize resource allocation, and enhance project outcomes.

Human-related factors, including effective communication, team coordination, and stakeholder engagement, also play a crucial role in the successful implementation of project management practices in manufacturing. Factors such as job satisfaction, competence of project team members, and effective communication channels are essential for fostering a collaborative and productive project environment (Kendra & Taplin, 2004). By prioritizing human factors and promoting a positive project culture, manufacturing companies can build strong project teams and drive project success. Additionally, external environmental considerations, such as market dynamics, regulatory requirements, and technological advancements, can influence the successful implementation of project management practices in manufacturing. Adapting to changes in the external environment, aligning project strategies with market demands, and leveraging technological innovations are essential for ensuring project success in a dynamic manufacturing landscape (Pacagnella et al., 2019). By staying attuned to external factors and proactively responding to market trends, companies can enhance their project management capabilities and drive successful project outcomes.

Long-term sustainability of efficiency improvements achieved through project management techniques

The long-term sustainability of efficiency improvements achieved through project management techniques in the manufacturing sector is crucial for ensuring continued success, competitiveness, and growth. By implementing effective project management practices and strategies, manufacturing companies can not only achieve short-term efficiency gains but also sustain these improvements over the long term. Several key factors contribute to the sustainability of efficiency improvements in manufacturing, including leadership commitment, continuous improvement culture, technology integration, and adaptability to changing market dynamics. Leadership

commitment plays a pivotal role in sustaining efficiency improvements achieved through project management techniques. Strong leadership support and involvement are essential for driving organizational change, fostering a culture of continuous improvement, and ensuring that efficiency gains are maintained over time Fitriadi (2023). Leaders need to champion efficiency initiatives, allocate resources effectively, and provide guidance to project teams to sustain improvements and drive long-term success.

A culture of continuous improvement is another critical factor in ensuring the sustainability of efficiency improvements in manufacturing. By fostering a culture that values innovation, learning, and adaptability, companies can continuously identify opportunities for improvement, implement best practices, and optimize processes to enhance efficiency (Awonuga, 2024). Encouraging employee involvement, providing training on new methodologies, and recognizing and rewarding improvement efforts are essential for embedding a culture of continuous improvement within the organization. The integration of technology and digital transformation plays a significant role in sustaining efficiency improvements in manufacturing. Leveraging advanced technologies such as automation, data analytics, and artificial intelligence can help streamline processes, optimize resource utilization, and enhance decision-making capabilities (RONO, 2019). By embracing digital tools and platforms, manufacturing companies can drive operational efficiency, improve productivity, and adapt to changing market demands to sustain efficiency gains in the long run.

Furthermore, adaptability to changing market dynamics is crucial for sustaining efficiency improvements in manufacturing. The ability to respond to market trends, customer demands, and industry disruptions is essential for maintaining competitiveness and relevance in a dynamic business environment (Tito & Sarker, 2020). Manufacturing companies need to stay agile, monitor market changes, and adjust their strategies and operations to sustain efficiency improvements and meet evolving customer needs. Moreover, effective risk management practices are essential for ensuring the sustainability of efficiency improvements in manufacturing. By identifying potential risks, developing mitigation strategies, and monitoring performance metrics, companies can proactively address challenges and uncertainties that may impact efficiency gains (Chen & Yang, 2021). Robust risk management processes help safeguard against disruptions, ensure continuity of operations, and sustain efficiency improvements over the long term.

2.5 Project Management Techniques in Manufacturing: A Comparative Analysis of Their Impact on Production Efficiency

To understand the impact of project management techniques on production efficiency, a critical analysis of several empirical studies is essential. Each study provides unique insights, yet a comparative evaluation reveals commonalities and differences that can inform best practices and highlight research gaps. For instance, Aimee and Nkechi (2022) provide a comprehensive analysis of project management practices in the context of public construction projects in Rwanda. They emphasize the role of structured project management frameworks, such as the Project Management Body of Knowledge (PMBOK) and Agile methodologies, in enhancing project performance. Their

findings indicate significant improvements in time management and resource allocation, suggesting that adopting formal project management practices can lead to more efficient project delivery. This study, however, primarily focuses on the public sector, leaving open questions about the direct applicability of these findings to the manufacturing industry.

Contrastingly, Ala et al. (2012) developed a stochastic model aimed at optimizing production cycle times within the metal processing industry. Their approach highlights the critical role of statistical and probabilistic methods in identifying and mitigating delays in production processes. The model's success in reducing cycle times underscores the importance of data-driven decision-making and continuous process optimization, principles that are integral to both Lean and Six Sigma methodologies. Unlike Aimee and Nkechi's (2022) study, which focuses on broader project management practices, Ala et al. (2012) provide a more technical perspective, emphasizing the need for specific tools and techniques tailored to the manufacturing environment. Furthermore, Cuatrecasas-Arbós et al. (2015) focus on inventory management and manufacturing lead times. Their research demonstrates that effective monitoring and control mechanisms can significantly reduce production delays. By implementing Just-In-Time (JIT) and Kanban systems, manufacturers can streamline their operations, reduce excess inventory, and minimize lead times. This study's findings resonate with Lean manufacturing principles, which advocate for waste reduction and process efficiency. However, the study stops short of exploring the integration of these systems with other project management techniques, such as Agile or Six Sigma, which could potentially yield even greater efficiency gains.

Durakovic et al. (2018) extend the analysis to the implementation challenges and trends associated with Lean manufacturing. Their empirical research identifies common barriers to successful Lean implementation, such as resistance to change and lack of training. By addressing these challenges, organizations can better leverage Lean principles to enhance production efficiency. This study's critical insight is the recognition that technical solutions must be supported by cultural and organizational changes. This aligns with findings from Panayiotou, Stergiou, and Chronopoulos (2022), who implemented Lean Six Sigma toolsets and reported significant improvements in both production efficiency and quality control. Their case study highlights the synergistic effects of combining Lean and Six Sigma methodologies, providing a more holistic approach to process improvement.

On a similar note, Panayiotou, Stergiou, and Panagiotou (2022) emphasize the importance of low-cost, high-effect initiatives in small and medium-sized enterprises (SMEs). Their research suggests that SMEs can achieve substantial improvements by adopting Lean Six Sigma practices without the extensive resource investments typically associated with large-scale implementations. This is particularly relevant for SMEs in the manufacturing sector, where budget constraints often limit the scope of process improvement initiatives. The study advocates for a tailored approach that considers the unique challenges and opportunities within SMEs, thereby broadening the applicability of Lean Six Sigma.

Fernandez-Viagas and Framinan (2015) provide a nuanced perspective on the trade-offs between processing times and resource allocation. Their analysis of controllable processing times in project and production management reveals that optimal resource allocation can lead to significant reductions in processing times. This study's strength lies in its detailed examination of the relationship between resource inputs and time savings, offering valuable insights for manufacturers looking to balance efficiency with resource constraints. The findings complement those of Cuatrecasas-Arbós et al. (2015) by highlighting the importance of strategic resource management alongside process monitoring. However, while these studies provide valuable insights, there are notable inconsistencies and gaps. For instance, Aimee and Nkechi (2022) emphasize the broader benefits of structured project management frameworks, while Fernandez-Viagas and Framinan (2015) focus on the specifics of resource allocation and processing times. This discrepancy suggests a need for integrated research that combines the strategic perspectives of project management frameworks with the technical details of resource and process optimization.

Moreover, there is a lack of longitudinal studies examining the sustained impact of these methodologies over time. Most studies, such as those by Ala et al. (2012) and Panayiotou, Stergiou, and Chronopoulos (2022), provide short-term results without addressing the long-term sustainability of the improvements achieved. Longitudinal research could provide deeper insights into the durability of these efficiency gains and the factors that influence their persistence. Finally, while individual methodologies such as Lean, Six Sigma, and Agile have been studied extensively, there is limited research on their combined effects. Studies like those by Durakovic et al. (2018) and Panayiotou, Stergiou, and Panagiotou (2022) highlight the benefits of Lean Six Sigma, but there remains a gap in understanding how multiple methodologies can be integrated to maximize efficiency. This gap points to the potential for future research to explore hybrid approaches that leverage the strengths of various project management techniques.

Conclusion

In conclusion, the literature review underscores the critical inefficiencies prevalent in the manufacturing sector, with a particular focus on resource allocation, process optimization, and the adoption of advanced methodologies. Studies highlight persistent challenges such as resource misallocation, over-reliance on manual processes, and inadequate workforce training. The implementation of Lean Manufacturing and Six Sigma methodologies has shown significant promise in addressing these inefficiencies, though each has its limitations. Lean Manufacturing excels in waste reduction but struggles with variability, while Six Sigma's rigidity may not always adapt well to rapid market changes. The integration of advanced technologies like IoT, AI, and robotics presents significant potential for enhancing efficiency, though high adoption costs and interoperability issues remain barriers. Future research should focus on hybrid approaches that combine the strengths of different methodologies and investigate the long-term sustainability of efficiency improvements to provide a more comprehensive solution for the manufacturing sector's challenges.

CHAPTER THREE: RESEARCH METHODOLOGY

3.0   Introduction

The research methodology for this dissertation, titled "Reduction of Production/Processing Time in the Manufacturing Sector through the Application of Project Management Techniques," is designed to comprehensively address the research objectives and questions outlined. This study aims to explore how different project management techniques can effectively reduce production cycle times, identify key success factors for their implementation, evaluate the long-term sustainability of achieved efficiencies, and develop context-specific recommendations for various manufacturing environments. Hence this section discussed the research design, data collection, Sampling, Research Instruments, Data Analysis, and Ethical Considerations.

3.1   Research Design

The chosen research design for this dissertation is a mixed-methods approach, combining both quantitative and qualitative research methodologies. This method is particularly well-suited for this study as it allows for a more comprehensive and analysis of the research problem. By combining the strengths of both approaches, this design enables the triangulation of data, which enhances the validity and reliability of the research findings (Tashakkori & Teddlie, 2010). The qualitative data will provide depth and context to the quantitative findings, while the quantitative analysis will offer empirical support to the qualitative insights. This integrative approach ensures that the research findings are well-rounded, addressing both the 'how' and 'why' aspects of the research questions. This approach is particularly suitable as it allows for a comprehensive analysis of the impact of project management techniques on production and processing times in the manufacturing sector. By integrating quantitative and qualitative data, the mixed-methods approach provides a more complete understanding of research problems than either method alone (Creswell & Plano Clark, 2011).

3.1.1   Qualitative Research

The qualitative component of the research is designed to explore the deeper, contextual factors influencing the implementation and effectiveness of project management techniques. Qualitative research is particularly well-suited for understanding complex phenomena, such as organizational culture, leadership styles, and stakeholder engagement, which are critical in project management (Denzin & Lincoln, 2018). In this study, qualitative data will be gathered through semi-structured interviews with project managers, engineers, and other key stakeholders in the manufacturing sector. These interviews will allow for an in-depth exploration of the participants' experiences, challenges, and perceptions related to the adoption and execution of project management practices.

Thematic analysis will be employed to identify recurring patterns and themes within the qualitative data. This approach is justified by the need to uncover the underlying factors that contribute to or hinder the success of project management initiatives, as suggested by Braun and Clarke (2006). Additionally, case studies of specific manufacturing firms that have successfully implemented project management techniques will be conducted. Case studies are a powerful qualitative research tool, offering detailed insights into complex real-world issues within their natural context (Yin,

2018). These case studies will provide rich, contextualized examples of best practices and lessons learned, contributing to a more comprehensive understanding of the research problem.

3.1.2 Quantitative Research

Complementing the qualitative approach, the quantitative component of the research will involve the collection and analysis of numerical data to statistically evaluate the impact of project management techniques on production cycle times. Quantitative research is essential for establishing the extent of relationships between variables and for generalizing findings across larger populations (Creswell, 2014). In this study, quantitative data will be obtained through structured surveys distributed to project managers and operational heads in various manufacturing firms. These surveys will measure key variables such as the use of specific project management techniques, changes in production cycle times, and the perceived effectiveness of these techniques.

The data collected will be analyzed using statistical methods, including regression analysis and correlation analysis, to determine the strength and nature of the relationships between the implementation of project management techniques and the reduction in production times. The use of quantitative analysis is justified by the need to provide empirical evidence that supports or refutes the hypotheses generated from the literature review and qualitative findings (Field, 2017). Moreover, quantitative data will help to validate the qualitative perceptions, ensuring that the conclusions drawn are both strong and reliable.

3.1.3 Primary Research

Primary research forms the cornerstone of this study, enabling the collection of original data that is directly relevant to the research questions. The decision to conduct primary research is driven by the need to gather specific insights that are not readily available in existing literature, especially in the context of manufacturing operations. Through the collection of firsthand data, this research aims to bridge gaps identified in the literature review, offering a fresh perspective on the effectiveness and challenges of implementing project management techniques in manufacturing environments. According to Saunders, Lewis, and Thornhill (2019), primary research is crucial in exploratory studies where specific, context-dependent insights are required. By engaging with professionals in the field through surveys, interviews, and case studies, this research will capture nuanced information that secondary sources may not provide.

3.2 Data Collection

The choice of data collection instruments is critical to ensure that the research objectives are effectively addressed and that the data gathered is reliable and valid. In this study, a combination of interviews and questionnaires will be used to collect qualitative and quantitative data, providing a comprehensive understanding of how project management techniques influence production and processing times in the manufacturing sector.

3.2.1 Interviews

Type of Interview: The study will employ semi-structured interviews as the primary qualitative data collection instrument. Semi-structured interviews are particularly advantageous for this research as they allow for a balance between the flexibility of open-ended questions and the structure needed to ensure consistency across interviews (Bryman, 2016). This type of interview enables the researcher to explore specific themes in-depth while also allowing participants to express their views freely and introduce new perspectives that may not have been projected by the researcher.

Design of the Interview: The interview guide was carefully designed to cover key topics related to the research questions, such as the challenges and benefits of implementing project management techniques, the impact of these techniques on production cycle times, and the contextual factors that influence their success or failure. The interview guide includes open-ended and probing questions, allowing for in-depth exploration of the participants' experiences and perceptions. The use of open-ended questions is essential to gather rich qualitative data, as it encourages respondents to provide detailed responses based on the respondents' personal experiences (Kvale & Brinkmann, 2015).

Delivery of the Interview: The interviews will be conducted virtually via video conferencing platforms such as Zoom conference and Microsoft Teams, depending on the availability and preference of the participants. Video conferencing can provide flexibility and convenience, especially when participants are geographically dispersed (Opdenakker, 2006). As it is in this case where the interviewer is in the UK the interview will be done with respondents from manufacturing companies in Nigeria. All interviews will be recorded, with the participants' consent, to ensure accurate transcription and analysis of the data.

3.2.2 Questionnaires

Design of the Questionnaire: The questionnaire was designed to collect quantitative data that complements the qualitative insights gained from the interviews. It was structured to include closed and open-ended questions, providing a mix of quantifiable data and qualitative responses that add depth to the analysis. The closed-ended questions predominantly use a Likert scale format, where respondents will indicate their agreement level or disagreement with specific statements related to project management practices and their impact on production cycle times.

Likert Scale: The Likert scale is a widely used tool in survey research for measuring attitudes, perceptions, and behaviours, making it highly suitable for this study. A five-point Likert scale ranging from "Strongly Disagree" to "Strongly Agree" was used to assess participants' opinions on various aspects of project management techniques, such as their effectiveness, ease of implementation, and impact on efficiency. The use of a Likert scale enables the researcher to quantify subjective opinions, making it possible to perform statistical analyses on the responses (Joshi et al., 2015).

Layout of the Questionnaire: The questionnaire was carefully laid out to ensure clarity and ease of completion. It began with a brief introduction explaining the purpose of the study and assuring participants of the confidentiality of their responses. The questions were grouped into sections, each focusing on a specific aspect of the research, such as the type of project management techniques used, the perceived impact on production times, and the challenges encountered. Clear instructions was provided for each section, and the questions will be phrased in straightforward, unambiguous language to avoid confusion (Dillman, Smyth & Christian, 2014).

Delivery of the Questionnaire: The questionnaire was distributed electronically via email, WhatsApp, and other message means with a link to an online survey platform Google Forms. The use of an online platform allows for efficient data collection, as it enables the researcher to reach a larger sample and facilitates easy data management and analysis. Participants were given a set period to complete the questionnaire, and follow-up reminders was sent to encourage a high response rate. To increase engagement, the questionnaire was kept concise, with an estimated completion time of 10-15 minutes, ensuring that it is not overly burdensome for respondents.

Sampling
Quantitative Sample

To ensure statistical validity and generalisability of findings, this study aims for a sample size of at least 100 respondents from various manufacturing firms. This number balances the need for robust data with practical considerations of time and resource constraints. Stratified random sampling will be employed to ensure representation from different types of manufacturing sectors, such as automotive, electronics, and food processing. Stratified sampling is particularly effective in this context as it allows the researcher to ensure that subgroups within the population are adequately represented, thereby mitigating bias and enhancing the reliability of findings by including diverse perspectives (Etikan, Musa, & Alkassim, 2016).

Qualitative Sample

Approximately 5 semi-structured interviews with key stakeholders, including project managers and engineers, and detailed case studies will be conducted. This sample size is chosen to provide depth and richness of data, facilitating a comprehensive understanding of the implementation processes and challenges. Purposive sampling will be used for the qualitative component, allowing the selection of participants and case studies that are particularly knowledgeable about or experienced with the implementation of project management techniques. This method is justified as it focuses on information-rich cases that provide deep insights into the research questions (Palinkas et al., 2015).

3.3   Validity and Reliability

Ensuring the validity and reliability of the research instruments is crucial in producing credible and trustworthy results in any empirical study. Validity refers to the extent to which a research instrument measures what it is intended to measure, while reliability pertains to the consistency of the instrument in measuring the concept over time (Creswell & Creswell, 2018). For this

dissertation, focused on reducing production/processing time in the manufacturing sector through project management techniques, both validity and reliability are paramount to producing meaningful and generalizable findings.

3.3.1 Validity

Different types of validity must be considered: content validity, construct validity, and external validity. Content validity ensures that the instrument fully represents the construct being studied. To achieve this, the interview questions and questionnaire items will be developed based on a comprehensive review of the literature on project management and production efficiency, ensuring that all relevant aspects of the concepts are covered (Hayashi et al., 2019). Subject matter experts in project management and manufacturing will be consulted to review the research instruments, providing feedback to refine the questions and ensure that they are both comprehensive and relevant to the study's objectives.

Construct validity is concerned with whether the instrument accurately measures the theoretical constructs it is intended to measure. In this research, construct validity will be established through the operationalization of key concepts, such as project management practices and production time efficiency, ensuring that the questions reflect the underlying theoretical frameworks. The use of established scales and measures from previous studies will also contribute to construct validity by aligning the instruments with proven research practices (Trochim & Donnelly, 2008).

External validity, or generalizability, relates to the extent to which the findings can be generalized beyond the study sample to other contexts. While this research focuses on a specific sector, the manufacturing industry, efforts will be made to ensure that the sample is representative of various sub-sectors within manufacturing. This will enhance the generalizability of the findings across different manufacturing environments (Leedy & Ormrod, 2019). Additionally, the mixed-methods approach, combining qualitative and quantitative data, will provide a more holistic understanding of the phenomena, increasing the likelihood that the findings are applicable in broader contexts.

3.3.2 Reliability

Reliability refers to the consistency and stability of the measurement process. A research instrument is considered reliable if it produces consistent results when repeated under similar conditions. In this study, several strategies will be employed to ensure the reliability of the data collection instruments. **Test-retest reliability** will be assessed by administering the same questionnaire to a pilot group at two different points in time and then correlating the scores to measure stability over time (Bryman, 2016). If the correlation is high, the instrument can be deemed reliable in capturing consistent data.

Inter-rater reliability will be particularly important for the qualitative data collected through interviews. This will be addressed by having multiple researchers independently code a sample of the interview data and then comparing the consistency of their coding. Any discrepancies will be discussed and resolved to ensure that the coding process is reliable across different raters (Cohen

et al., 2018). This step is essential to reduce subjective bias and ensure that the qualitative analysis accurately reflects the participants' responses.

Internal consistency reliability, which refers to the degree to which items within a questionnaire are consistent in measuring the same construct, will be measured using Cronbach's alpha. A Cronbach's alpha coefficient of 0.7 or above will be considered acceptable, indicating that the items in the scale are reliably measuring the same underlying concept (Field, 2018). This statistical measure will be applied to the Likert scale items in the questionnaire to ensure that the different items contribute consistently to the overall construct.

Data Analysis

Quantitative Analysis

Quantitative data collected through questionnaires will be analysed using statistical methods such as regression analysis, ANOVA (Analysis of Variance), and correlation analysis. Regression analysis will help identify the relationship between the use of specific project management techniques and the reduction in production cycle time. ANOVA will compare the effectiveness of different project management techniques across multiple manufacturing firms. Additionally, correlation analysis will examine the strength and direction of relationships between variables, such as the extent of project management implementation and the degree of time reduction achieved. The use of statistical methods such as regression analysis, ANOVA, and correlation analysis is essential for identifying relationships and comparing the effectiveness of different project management techniques in reducing production cycle time. Descriptive statistics summarise the data and highlight patterns or anomalies, while reliability and validity checks ensure the robustness of the questionnaire data (Mertler & Vannatta, 2017; Tavakol & Dennick, 2011).

Descriptive statistics will be employed to summarise the survey data. Measures such as mean, median, mode, standard deviation, and frequency distributions will provide an overview of the prevalence and effectiveness of different project management practices within the sample population. These descriptive statistics are crucial for presenting the data in a comprehensible manner and for identifying patterns or anomalies that warrant further investigation (Mertler & Vannatta, 2017).

Ensuring the reliability and validity of the questionnaire data is vital. Cronbach's alpha will be used to assess the internal consistency of the questionnaire items, ensuring that they reliably measure the intended constructs (Tavakol & Dennick, 2011). Construct validity will be evaluated through factor analysis, ensuring that the questionnaire accurately captures the dimensions of project management practices and their impact on production time.

Qualitative Analysis

Qualitative data from interviews will be analysed using thematic analysis, a method for identifying, analysing, and reporting patterns (themes) within data (Braun & Clarke, 2006). This approach involves coding the data, searching for themes, reviewing themes, defining and naming themes,

and producing the report. Thematic analysis will help uncover the critical success factors, barriers, and context-specific adaptations related to the implementation of project management techniques. Thematic and content analyses are chosen for qualitative data to systematically uncover patterns, success factors, and barriers related to project management implementation. These methods complement the quantitative analysis, providing a comprehensive understanding of the research problem (Braun & Clarke, 2006; Krippendorff, 2018).

Additionally, content analysis will systematically categorise qualitative data to draw meaningful inferences. This method involves coding the data into predefined categories, which helps manage large volumes of qualitative information and facilitates the identification of trends and patterns (Krippendorff, 2018). By triangulating the findings from content analysis with quantitative results, the study ensures a comprehensive understanding of the research problem.

Ethical Considerations

Ethical considerations such as informed consent, confidentiality, and ethical approval are crucial to protect participants' rights, ensure privacy, and maintain research integrity. These measures align with ethical standards and legal requirements, promoting trust and compliance (Wiles, 2012; Babbie, 2016; Resnik, 2018).

Informed Consent

Obtaining informed consent from all participants is a fundamental ethical requirement. Participants must be fully informed about the nature, purpose, and potential risks of the study before they agree to participate. This includes providing clear information about how their data will be used and ensuring they understand that participation is voluntary (Wiles, 2012). Informed consent ensures respect for participants' autonomy and protects their rights.

Confidentiality

Maintaining the confidentiality of participants is crucial to protect their privacy and build trust. Personal identifiers will be removed from the data, and anonymised codes will be used during analysis. Data will be securely stored, and only authorised personnel will have access to it. This ensures compliance with ethical standards and data protection regulations (Babbie, 2016).

Ethical Approval

Before commencing data collection, ethical approval will be sought from the relevant institutional review board (IRB). The IRB will review the research proposal to ensure that it complies with ethical guidelines and that potential risks to participants are minimised. Ethical approval is necessary to safeguard the welfare of participants and maintain the integrity of the research process (Resnik, 2018).

Summary

The chosen sampling methods and research instruments are designed to comprehensively address the research objectives and questions. Stratified random sampling and purposive sampling ensure representative and information-rich samples, respectively. The questionnaire, as the primary quantitative instrument, offers efficiency, standardisation, and broad reach, while the semi-structured interview guide and case study protocol provide depth and contextual understanding. Together, these methods and instruments form a robust framework for investigating the impact of project management techniques on production and processing times in the manufacturing sector.

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