RELATIONSHIP BETWEEN PRODUCT DESIGN, LEAN MANUFACTURING AND OPERATIONAL PERFORMANCE OF SUGAR FIRMS IN KENYA

BY

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MASENO UNIVERSITY

DECLARATION

This thesis is entirely my original work with no prior submissions to other Colleges or Universities for assessment.

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With our consent as university supervisors, this study proposal has been submitted for assessment.

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DEDICATION

With boundless love and gratitude, I dedicate this thesis to my beloved wife Pacifica Bwogo, and our precious daughter Kylieflorence, whose unwavering support and presence have been my guiding light throughout this journey. To my dear parents, Thomas Kerongosi and Florence Akama, and to my cherished sisters, brother, nephews, and nieces, your constant encouragement and belief in me have been an endless source of inspiration. This accomplishment is a testament to the love and strength of our family bond, and I am forever grateful for each one of you.

ABSTRACT

The Sugar Firms in Kenya contribute approximately 26% directly to the Gross Domestic Product (GDP) and an additional 25% indirectly through agro-based and associated industries linkages. However, they have experienced a significant decline of milled sugar production from 523,652 metric tones in 2010 to 440,935 metric tones in 2019 according to in the sugar sub-sector report by Kenya Association of Manufacturers in 2020. This decline was mainly attributed to the high cost of production stemming from inefficiencies across the value chain from inadequate research and extension leading to the design of production systems that are inefficient. Despite the vast contribution of the sugar firms to the economy, this problem of inefficient production system has not been solved and thus the Sugar Firms performance continues to spiral downward leading to the dissolution of some firms, downscaling of operations. The reviewed studies revealed an absence of a clear association among the three variables. They also indicating a weak relationship between product design and operational performance, underscoring the necessity for introducing a lean manufacturing as a moderator to enhance understanding and potentially strengthen the intricate interplay between product design and operational performance. Product design, lean manufacturing, and operational performance practically exist together, since lean manufacturing boosts product design by eliminating waste and consequently elevates operational performance, on the contrary, based on the reviewed studies, there has been an absence of research endeavors aimed at establishing the association of this three variables. It is in this regard that this study purposes to establish the relationship between product design, lean manufacturing, and operational performance of Sugar Firms in Kenya. Specifically this study seeks to determine the effect of product design on operational performance of Sugar Firms in Kenya, to establish the effect of lean manufacturing practices on operational performance of Sugar Firms in Kenya, and to establish the moderating effect of lean manufacturing practices on the relationship between product design and operational performance of Sugar Firms in Kenya. The research was guided by the resource-based view theory and transaction cost theory. This study was guided by a correlational research design. A census survey was conducted targeting all 164 managers and assistant managers of Sugar Firms in Kenya. A pilot study was conducted of 14 participants constituting of managers and assistant managers of seven departments in Transmara Sugar Company to test for reliability using Cronbach‘s alpha, with a threshold of 0.70, indicating satisfactory instrument reliability. The Cronbach's Alpha reliability coefficient obtained in this study was 0.849. Primary data was collected using questionnaires. The study was based on three fundamental ways of assessing the validity of the research instrument which include; criterion, content, and construct. A multiple linear regression model was applied to establish the association among explanatory variables in this study. The results established that product design significantly affects operational performance (β =0.742, p=.000), hence, adoption of product design yields a significant 0.742 unit increase in operational performance for Sugar Firms. Indicating a positive and significant association between the two variables. Lean Manufacturing had a significant positive effect on operational performance (β=0.661, p=0.000), suggesting that the implementation of lean manufacturing practices leads to 0.661 unit increase in operational performance. After incorporating the interaction effect, the R square change was 0.008 (p=0.048), indicating that lean manufacturing statistically moderates the relationship between product design and operational performance by 0.8%. It was concluded that supply chain management played a more prominent role in determining product design compared to digital technologies which had the lowest prevalence in that regard. Consequently, it was concluded that lean manufacturing is a crucial and influential factor in shaping the operational performance of Sugar Firms in Kenya. Finally the study concludes that lean manufacturing plays a significantly moderates relationship between product design and operational performance, providing valuable insights for enhancing these aspects within the manufacturing context of Sugar Firms. Thus, the study recommends that Sugar Firms' Management should focus on maintaining a robust product design while integrating lean manufacturing practices to enhance operational performance. By adopting the provided lean manufacturing model, they can effectively strengthen the relationship between product design and operational performance. This approach is likely to lead to improved overall performance and efficiency in the sugar firms' manufacturing processes. The study may have a significant impact: to the government by aiding in the formulation of policies, to the sugar sub-sector by aiding them to focus on a robust manufacturing system with a paradigm shift from loss marking to profit-making institutions and a hub for the creation of employment and the world of academia may contribute to the increasing body of literature on operations management activities.

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LIST OF ABBREVIATIONS

CI - continuous improvement

CIM - computer-integrated manufacturing

GDP- gross domestic product

JIT – Just in time

KAM - Kenya Association of Manufacturers

KIPPRA - Kenya Institute for Public Policy Research and Analysis

KNBS - Kenya National Bureau of Statistics

LM - Lean Manufacturing

NACOSTI - National Council for Science, Technology and Innovation

RBV - Resource Based view

Sony - South Nyanza

TPM -total productive maintenance

VIF - variance inflation factor

VSM - value stream mapping

WTB - willingness to buy

OPERATIONAL DEFINITION OF TERMS

Continuous improvement- is a lean manufacturing transformation technique that oversees and upgrades the transformation process by increasing quality, efficiency, and profits through ensuring quality control, standard work, use of efficient equipment, and elimination of waste.

Digital technologies – is the use of technology that helps improve business operations

E-manufacturing – is a manufacturing technique that integrates the use of computers in manufacturing systems.

Just in time- is a principle of lean manufacturing that ensures a company enjoys a competitive edge by ensuring inputs in the transformation process are only considered based on customer orders by boosting value-adding activities.

Lean manufacturing- is a production technique that is oriented towards the elimination of waste in the manufacturing system, to lower the cost of production and increase the quality of the goods or services to maximize customer satisfaction and elevate the company's operational performance.

Manufacturing cost - is the total cost of resources utilized in the transformation process during the production of goods.

Operational performance - is an interdepartmental management approach that aims at achieving the set targets of a company economically.

Product design – is the link among the marketing (consumer ideas), finance (for facilitation), and research & innovation (for review) with an over whole interface of operations management (for development and adoption) to develop or review a production system guided by its characteristic and dimensions..

Product quality – the degree to which a product/ service or combination suits the customer´s specifications.

Production dependability – is the company´s capacity to deliver quality products promptly as requested by customers.

Production flexibility- is a production system's capability to quickly adjust and cost-effectively produce products that meet customer expectations.

Quality function deployment - This is a production technique adopted to satisfy customer desires

Speed of production – is the duration taken between a customer placing an order and the customer being issued with the ordered product.

Sugar firms- Also known as sugar companies, are firms that specialize in business for the production and distribution of sugar and sugar-related products.

Supply chain management - is a strategic and integrated approach to orchestrating key business functions, encompassing design, procurement, production, logistics, and distribution to ensure a seamless flow of goods, services, and information from concept to consumer...

Total product maintenance- is a technique that helps to ensure zero accidents and zero defects by ensuring overall equipment effectiveness

Value stream mapping- is a technique that identifies and eliminates waste from a manufacturing system by examining the movement of material and information currently needed to deliver a product to the desired customer.

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CHAPTER ONE

INTRODUCTION

This chapter establishes an outline of the research framework by establishing contextually the concepts of product design, lean manufacturing, and operational performance, deriving a statement of the problem. Segmenting in chapter one entailed the following: background to the study, statement of the problem, research objectives, research hypotheses, scope of the study, study justification, and conceptual framework.

1.1 Background to the Study

Transformation process in manufacturing companies is the primary function of operations management, involving the processing of inputs into finished goods and services (Domingues & Machado, 2017; Fiorentino, 2016; Reid & Sanders, 2012). Further, operations management is a division of administration responsible for business practices by ensuring maximum efficiency in the organization and it is key in business organizations in order to attain their objectives and set goals, Yasin and Naeesha (2019) and for operations management impact to be realized, the operations department should target value addition in the product line, by ensuring that the grand increase among the output value of products or services relative to the significant value of inputs, (Pham & Gobetto, 2021). Operations management's key functions entail location, supply chain management, product design, maintenance, process design, quality management, layout design, inventory, human resources, and scheduling (Heizer *et al*., 2017). Product design is the key indicator for successful operational performance realization (Roble & Wanjira, 2021). Chary (2012) product design is the heart of all functions in a manufacturing company.

The key aim of product design is to ensure that customer interests are addressed in the production transformation process at lower production costs (Sabir, 2020). For this to be achieved operations managers adopt concurrent engineering for robust transformation from the design stage to the actual production while addressing production time and cost with enhanced quality in mind. Indicators such as e-manufacturing, supply chain management, and quality function deployment proposed by Heizer *et al*. (2017); and digital technologies proposed by Sayar and Er (2019), can be adopted by manufacturing companies for effective implementation of product design. And their adoption in the production line may result in lower production costs, enhanced quality, and reduced production time. Therefore globally most production lines have been decentralized resulting in manufacturing firms experiencing production breakdowns. It is eminent for manufacturing firms to review their production lines with the advent of the global markets focusing on their product designs. According to United Nations Industrial Development (2020), the global manufacturing growth rate declined in two subsequent years declining to a marginal rate of 2% in 2019. Decline in production can be due to high cost of production resulting to reduced revenues, throughput inefficiency, delays in delivery, lost market share and insufficient institutional capacity.

The term "product design" and the frameworks associated with it are not mutually understood (Homburg *et al*., 2015). This is because product design is customized from one product line guided by consumer perceptions and production dimensions (Bloch, 2011). Product design is a set of unified elements of consumer perceptions, organized as a multifaceted union entailing 3 aspects; functionality, symbolism and aesthetics (Bloch, 2011; Homburg *et al*., 2015; Luchs & Swan, 2011). According to Edwards (2014) product design is the incorporation of technical and industrial designs with the intent of producing products. Reid and Sanders (2013) further provided a feasible definition of product design as the process of establishing the appearance, materials, dimensions, tolerances, and performance standards of a company. Bleda *et al*. (2021) and Roper, (2016) on the other hand defined product design as an interface between product development and innovation. Based on the robust definitions of product design, can be defined as is the link among the marketing (consumer ideas), finance (for facilitation), and research & innovation (for review) with an over whole interface of operations management (for development and adoption) to develop or review a production system guided by its characteristic and dimensions.. Jindal *et al*. (2016) classified product design into three dimensions: form, function, and ergonomics. The following indicators were adopted in this study to measure product design: e-manufacturing, supply chain management, and quality function deployment as proposed by Heizer *et al*., (2017); and digital technologies proposed by (Sayar & Er, 2019).

Firms' production lines are vulnerable to lack of customer knowledge, poor communication between production teams, and wastes, resulting in inefficiency in production hence the need for the adoption of product design. Product design is the lead segment in the assessment of the product's life cycle because its implementation directly affects materials, quality, cost, processes, associated packaging and logistics, and ultimately the product supply chain (Heizer *et al*., 2017). Product design also defines product specifications, raw materials, and bought-out parts, and moderates the contracts with the customers (Chary, 2012). Besides, that product design is the cornerstone for the development of any business strategy(Schroeder *et al*., 2016).

This research adopted the subsequent indicators in measuring product design: e-manufacturing proposed by Reid & Sanders, (2013) supply chain management and quality function deployment proposed by Heizer *et al*. (2017); and digital technologies proposed by (Sayar & Er, 2019).

Ahmad *et al*. (2018); Bagshaw (2017); Coudounaris (2018); Gao *et al*. (2021); Kariuki (2016); Kwaku and Fan, (2020); Putri and Rofiq (2020); Roble and Wanjira (2021) conducted studies on the relation between product design and operational performance and established presence of a positive association between product design and operational performance. Despite their findings, each study had limitations and weaknesses of their own. Roble and Wanjira, (2021) anchored their study on the commercial banks in Garissa County and did not factor in other regions with more stabilized commercial banks in contrast to the growing county. The study did not factor in lean manufacturing (LM) as a moderator. Besides that, a study conducted by Gao *et al*., (2021) demonstrated a weak association of ($\beta = 0.27$, $p < 0.001$) as compared to the present research which demonstrated a more positive and significant connection between variables. Kariuki, (2016) did not use any moderating variable to measure the extent to which product design can impact a firm's operational performance. Bagshaw (2017) the study focused on a confined geographical area which might limit the applicability of the study's findings to a broader context. The study did not also define the appropriate survey design to adopt during data collection given that the researcher was studying the entire and small target population. Ahmad *et al*., (2018) adopted a questionnaire method to collect data from 400 respondents and out of which only 80 responded representing 20% of the target population. This is a small response rate (20%) meaning that the study suffered 80% nonresponse biasness of hence commemorating to biased conclusions. Kwaku and Fan, (2020) adopted purposive sampling which has a possibility of biasness. Putri and Rofiq, (2020) study did not take into account e-manufacturing, quality function deployment, supply chain management, and digital technologies which are important metrics for evaluating product design. Coudounaris, (2018) adopted an online survey which is prone to non-response bias, as survey fraud is eminent when conducting online surveys. The respondent margin was very small compared to the sample population, hence may prevent the findings from being extrapolated.

Previous similar studies endeavored to define the influence of product design in relation to a company's operational performance. Rincon-Guevara et al., (2020) while writing on product design and manufacturing system operations an integrated approach for product customization in the USA focused on product upgradability and flexibility. Bagshaw, (2017) while looking at the process and product design: production efficiency of manufacturing firms in Rivers State, Nigeria observed that both designs for process and product are significant and positively influence production efficiency. Roble and Wanjira, (2021) while looking at the effects of product design on performance of commercial banks in Garissa County, Kenya rated on a scale focused on unique products, reliability, and integration. As indicated all the previous studies did not consider e-manufacturing, quality function deployment, supply chain management, and digital technologies as measuring indicators of product design studies.

Previous studies adopted metrics that were limited and could not, therefore, yield valid results on the impact of product design on operational performance. Similarly, an attempt by previous scholars to establish a metric of operational performance so us to determine the influence of product design applied weak measures of operational performance with a focus on the input and output wastes rather than the whole manufacturing system which is key in any manufacturing organization's transformation process. With the view of addressing this most studies (Everaert & Swenson, 2014; Kropivšek *et al*., 2021; Tornberg *et al*., 2002; Wedowati *et al*., 2020) adopted activity-based costing, however, it is criticized by Balakrishnan *et al*., (2015) who disputed that it is resource intensive and time-consuming making them unable to address the issue of short time delivery and limited utilization of resources in the product line guided by the product design. Despite the voluminous scholarly writings to evaluate the connection between product design and operational performance, justification of e-manufacturing proposed by Reid and Sanders, (2013) supply chain management and quality function deployment proposed by Heizer *et al*., (2017); and digital technologies proposed by Sayar and Er, (2019) which forms product design metrics are applied in establishing the influence of product design on operational, is however missing. This research investigation revealed that e-manufacturing, quality function deployment, supply chain management, and digital technologies established ($\beta = 0.267$, $p = .000$; $\beta = 0.281$, $p = .000$; $\beta = 0.337$, $p = .000$ and $\beta = 0.154$, $p = .000$) respectively. All the four proposed sub-indicators of product design demonstrated positive and statistically significant relationships with operational performance. Hence, proving a robust scientific prove that they constitute a robust metric for measuring product design.

With the advent of limited raw materials, Toyota began to adopt lean manufacturing practices so as to lower the cost of production and to advance a variety of manufactured models which in return would better place them in the global market (Kiran, 2022). Lean manufacturing is a production technique that prioritizes removing inefficiencies and strives for continuous improvement to achieve higher efficiency levels and cost savings by eliminating waste (Kumar *et al.*, 2022). Johan and Soediantono (2022) lean manufacturing has extensively been adopted in diverse industries to enhance improve productivity, reduce lead time, enhance customer satisfaction, and advance the company's competitiveness. Palange and Dhatrak (2021) also postulated that companies utilizing lean manufacturing practices enjoy an efficient supply chain, increased productivity, reduced production costs & involvement of personnel, reduced inventory, and advanced response to production breakdown. While there is substantial literature demonstrating the positive impact of lean manufacturing (LM) on efficiency, cost reduction, and overall competitiveness (Kiran, 2022; Kumar *et al*., 2022; Johan & Soediantono, 2022; Palange & Dhatrak, 2021), a notable gap exists in our understanding of how LM moderates the relationship between product design and operational performance. Little attention has been directed towards exploring the nuanced dynamics between product design decisions and the implementation of lean manufacturing practices, leaving a significant knowledge gap in comprehending the full spectrum of influences on operational performance within diverse industries.

Lean manufacturing is defined as a logically organized production system with the intent of identifying and eliminating waste by practicing routine and continuous improvement with the aim of adopting a smooth supply chain (Silva, 2012). Waste is anything that is not adding value to any activity (Suhardi *et al*., 2019). Womack & Jones, (2003) established eight types of waste: motion, correction waste, unnecessary transportation waste, waiting waste, knowledge waste, inventory waste, over-processing waste, and overproduction waste. Rocha-Lona *et al*., (2013) established four main lean manufacturing practices in use today; total product maintenance (TPM), just-in-time (JIT), continuous improvement (CI), and value stream mapping (VSM).

Universally many companies are focused on the adoption of practices that are oriented to eliminate waste from their operations management activities to elevate their production systems Santibanez *et al*., (2019) but they cannot fully manage the dynamic product designs which are evolving over time (Shivankar & Deivanathan, 2021). In order for firms to effectively utilize operations management practices, they should focus on reviewing their product designs from time to time (Roble & Wanjira, 2021). Product design is the backbone of all operations in an organization (Chary, 2012). Product design not only affects operational performance but also determines the components constituting a product and defines their makeup to yield the desired output by functioning as a union (Naderi *et al*., 2020). In view of this, product design is gaining robust momentum among companies as a survival and growth strategy (Bagshaw, 2017). However, due to limited resources and waste in the production systems, though not significant, product designs must be treated with care, to ensure efficiency in the production line for a company to be on the competitive edge. The current production landscape in companies is therefore guided by the implementation of lean manufacturing practices in respective operations, so as to minimize waste in the production lines for them to ensure minimized production cost, production efficiency and to be competitive universally. Product design, lean manufacturing and operational performance are therefore a union for efficiency in any production (Basu *et al*., 2021; Pullan *et al*., 2013; Susilawati *et al*., 2015).

Lean manufacturing discipline is gaining robust momentum among manufacturing firms (Abolhassani *et al.*, 2016). This is because adoption of LM leads to significant increase in the operational performance of the firm at the expense of minimized waste in the production system (Shi *et al*., 2019). As a result, the adoption of lean manufacturing practices by manufacturing firms is encouraged because it elevates them against their competitors by rationalizing their production systems (Zahraee *et al*., 2020). Similarly, Lazai *et al*., (2020) established that applying lean manufacturing practices has a big impact on a company's success as it reviews its production process by ensuring efficiency and reducing the cost of production. Besides that, Lean manufacturing is oriented toward meeting customer demands by manufacturing of products and services with optimal cost efficiency, in regard to the evolving customer demands (Bhamu & Sangwan, 2014).

Previously reviewed research examining the correlation between LM and operational performance remains inadequate. Similar studies conducted prior, this study was looking at determining the correlation between LM and operational performance. For instance, prior review studies, Hernandez-Matias *et al*., (2019) establishing Lean manufacturing and operational performance focused on lean production managers and front-line supervisors of 202 Spanish companies in Spain concentrated on interconnectedness between human-related lean practices. Seng *et al*., (2021) while studying the industry 4.0 and lean manufacturing practices: an approach to enhance operational performance in Singapore’s manufacturing sector with a total of 51 companies were sampled giving attention to the integration of lean and industry relation 4.0. Nawanir, (2016) while studying the effect of lean manufacturing on operations performance and business performance in manufacturing companies in Indonesia involving 174 large manufacturing companies focused on the functions of lean manufacturing (LM). Besides that, Malonza, (2014) employed the theory of constraints to explore the effect of lean manufacturing on operational performance of Mumias Sugar Company Limited, Kenya only focused on lean manufacturing tools, further, the case study was too small to be used for the purpose of generalization.

Based on the reviewed studies above, lean manufacturing influence on operational performance, basically they concentrated on the general aspect of lean manufacturing tools and the perspective of the manufacturing system. As a result, they were not able to establish the best practices to be adopted in a manufacturing system and how they can be adopted to boost operational performance of the companies under study. This study adopted the four LM principles (total product maintenance (TPM), just-in-time (JIT), continuous improvement (CI), and value stream mapping (VSM) proposed by (Rocha-Lona *et al*., 2013). Similarly, in attempts to determine lean manufacturing's influence on operational performance, they adopted unexclusive metrics of operational performance by focusing on only the effect of the interests of stakeholders rather than the firm's operational performance as an overall primary purpose of existence of a company.

So as to solve such, majority of studies in this area (Everaert & Swenson, 2014; Kropivšek *et al*., 2021; Tornberg *et al*., 2002; Wedowati *et al*., 2020) have opted on adopting activity-based costing protested by Balakrishnan *et al*., (2015) who disputed that it is resource intensive and time-consuming making them unable to address the issue of short time delivery and limited utilization of resources in the product line guided by the product design. This implies that it does not take into account the wastes in the manufacturing system during the transformation process. Hence, wastes in the manufacturing system may not be realized and mitigated during production hence jeopardizing the application of principles of lean manufacturing.

Notwithstanding previous studies, efforts to determine the correlation between LM and operational performance, still there is a gap. If explored using proposed indicators of lean manufacturing practices that help operations managers as they model/ review the manufacturing systems to attain a waste-free transformation process by coming up with an efficient procedure of utilizing the 4 LM principles were directly affect the operational performance. The resilient operational performance indicators combining and manufacturing system performance indicators embraced by various scholars are utilized and this calls for an inquiry.

Wastes in the production line can lead to tangible and adverse effects on a company's operational performance (Alkhoraif & McLaughlin, 2018; Basu *et al*., 2021; Bhamu & Sangwan, 2014). Since product design is focused on the review or development of production lines, it was of great impact once incorporated with lean manufacturing to eliminate waste. Besides that Abdillah and Puspita, (2022) product design has no positive significant effect on purchasing decisions, while, A study conducted by Kariuki, (2016), established that there is a positive and statistically significant association R-squared value of 0.767 ($p = 0.002$) between product design and manufacturing system operations. Hence, there is a need for the adoption of lean manufacturing as a moderator to address such mixed results and weak relations between product design and operational performance.

Moderating effect is stirred by variables whose discrepancy affects the quality of the link between an independent variable and a dependent variable (Baron & Kenny, 1986; Lai, 2013). The results of the moderating influence are termed moderator variables or moderators (Fassott *et al*., 2016). The moderation effect stipulates a way to analyze if the intervention leads to uniform outcomes among the groups (Farooq & Vij, 2017). This study was guided by a moderating variable. This is because a moderating variable affects the trajectory of the influence of an initiator to the conclusion (Aguinis *et al*., 2017). The choice of a moderating variable should be informed on the basis of strong theoretical support Farooq & Vij, (2017), hence this informed the choice of RBV theory and transactional cost theory.

Lean manufacturing induces operational performance as established by Hernandez-Matias *et al*., (2019), Malonza (2014), Nawanir (2016), Seng *et al*., (2021). Wastes in the production line are unavoidable (Lazai *et al*., 2020; Shi *et al*., 2019; Zahraee *et al*., 2020) and come in various states (Goshime *et al*., 2019). As a result, in order to safeguard the interest of both internal and external stakeholders, production ought to continue by enhancing services to customers, ensuring high quality of the products produced, reducing production time, continuity in production, and benefiting manufacturing firms by increasing sales volumes, reducing the cost of production per unit and increasing market share. In the landscape of manufacturing literature, a notable gap exists pertaining to the empirical exploration of the correlation between product design, lean manufacturing, and operational performance. While previous studies (Hernandez-Matias et al., 2019; Malonza, 2014; Nawanir, 2016; Seng *et al*., 2021) have convincingly established the positive impact of lean manufacturing on operational performance, and acknowledged the inevitability of wastes in production processes (Lazai *et al*., 2020; Shi *et al*., 2019; Zahraee *et al*., 2020), there remains a distinct absence of scholarly research that delves into the intricate relationship among product design, lean manufacturing, and operational performance constructs.

In relation to the literature reviewed, there was none-existence of scientific prove directly examining the moderating effect of lean manufacturing on the association between product design and operational performance. Though there are studies done that give a clue of a possible relationship between product designs, lean manufacturing, and operational performance having determined lean manufacturing as an architecture of product design and operational performance. Rincon-Guevara *et al*., (2020) while writing on product design and manufacturing system operations, an integrated approach for product customization was guided by the development process, design alternatives, and product life cycle indicators. Fernandes and Canciglieri, (2014) focused on sustainable product design by developing a conceptual model for method-integrated product development in Brazil was guided by the development process, design alternatives, and product life cycle indicators. Ahmad *et al*., (2018) focused on the impact of product design and process design on new product performance in the manufacturing industry, and utilized a nationwide sample comprising100 Malaysian companies to establish the association between product design and process design on new product development, however, they focused on new product and new product process designs. Liu *et al*., (2019) carried out a study on the impact of product-design strategies on the operations of a closed-loop supply chain in China focused on remanufacturing strategy. A study by Kariuki, (2016) to determine production system design and operational performance of steel manufacturers in Kenya gave attention to adopted production system and operational performance.

Within the realm of existing literature, while theoretical recommendations and pragmatic efforts have been made, a critical void remains unaddressed: the absence of any study that systematically explores the moderating impact of lean manufacturing on the intricate relationship between product design and operational performance. Despite the wealth of knowledge and insights provided by previous research (Hernandez-Matias *et al*., 2019; Malonza, 2014; Nawanir, 2016; Seng *et al*., 2021), the specific examination of how lean manufacturing influences the dynamics between product design and operational performance remains largely uncharted. Scientific proof regarding the moderating significance of lean manufacturing in the association between product design and operational performance is conspicuously absent. This research aims to bridge this gap by introducing lean manufacturing as a third indicator, thereby delving into the unexplored terrain of its potential moderating effects. Manufacturing companies, upon incorporating lean manufacturing practices, stand to benefit by not only establishing mechanisms to mitigate routine wastes in the production line but also by crafting a robust product design strategy. This, in turn, has the potential to reshape the narrative surrounding poor operational performance in manufacturing contexts. In essence, this study serves as a pioneering effort to unravel the moderating role of lean manufacturing in the intricate interplay between product design and operational performance. By empirically examining these relationships, the research endeavors to contribute substantively to both theoretical understanding and practical applications within the manufacturing domain. The introduction of lean manufacturing as a moderating variable is poised to offer new perspectives and actionable insights for manufacturing firms seeking to optimize their operational efficiency and enhance overall performance.

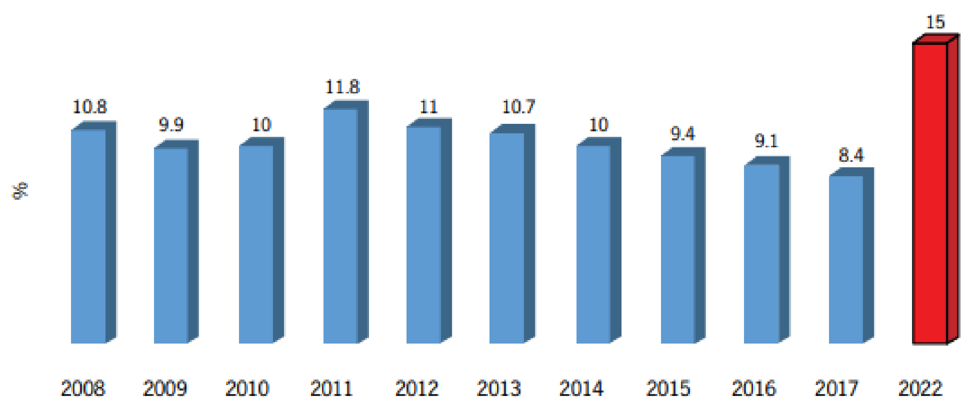
Operational performance has become the most current production term both by practitioners and academicians. Since there is no comprehensive definition of operational performance, most academics and practitioners are restricted to their affiliated disciplines. Operational performance is the strategic scope a company opts to adopt to gain a competitive edge (Chavez *et al*., 2015). Measurement of the manufacturing systems operational performance elevates manufacturing companies economically and sustainably. Hence the study adopted five standalone metrics: speed of production, production quality, production flexibility, product dependability, and cost of production to measure operational performance proposed by Slack & Brandon-Jones (2018).

There is no specific theory that develops an interface between product design, LM, and operational performance. However, resource-based view theory and transaction cost theory have a common understanding that firms operate in an environment of limited resources and for them to attain a competitive edge, they suggest that the manufacturing firms should design their transformation process so as to attain economic feasibility by reducing the cost of production. RBV and transaction cost theory constitute a framework that appreciates the adoption of product designs, and they appreciate that production is prone to experience wastes. Lean manufacturing can be used to eliminate them thus elevating the operational performance of a company. As a result, this research was anchored on the transaction cost theory and resource-based view to explain the interface among product design, lean manufacturing, and operational performance.

Kenya’s manufacturing industry is the key driver for fostering economic growth, according to Kenya’s Second Medium Term Plan (2013-2017), (2013). Despite that understanding, in the last seven years (2008 to 2014), the Kenyan manufacturing sectors contributes an average of 10% to its gross domestic product (GDP) and has been on a declining tendency, contributing

8.4% to GDP in 2017 Kenya Association of Manufacturers, (2019) as shown in (Figure 1.1). Similarly, the Kenya Association of Manufacturers, (2022) report indicates that the manufacturing sector's contribution to Kenya's GDP has experienced a continuous decrease, declining from 12.05% in 2011 to 7.61% in 2020. According to the Kenya Institute for Public Policy Research and Analysis - KIPPRA (2018) the manufacturing industry is vital for a country to attain its agenda for development. However, the manufacturing sector's contribution to the GDP has been deteriorating over the years like in 2017 it declined to 8.4% from 9.1% in 2016 as demonstrated in Figure 1.1.

Figure 1. 1: Contribution of the Manufacturing sector to GDP in the period: 2008- 2017



Data source: (Kenya National Bureau of Statistics, 2018)

A comprehensive and dynamic domestic manufacturing foundation is significant to attaining successful economic development, because it supports the generation of virtuous and collective linkages with other sectors of the economy driven by technological progress, and has the strongest potential for productivity gains (UNCTAD, 2016). Most of the developed countries attained it through the process of industrialization (Sheehan, 2008). Industrialization involves the transformation process of the economy from a primarily agricultural one to one based on the manufacturing of goods, which results in an increase in manufacturing value added to the Gross Domestic Product. Kenya unluckily in the manufacturing industry's frequency of contribution to GDP has been on deteriorating from 11.8% in 2011 to 8.4% in 2017 (UNCTAD, 2016).

The sugar sub-sector contributes about 26% to the GDP and an additional 25% to the agro-based and related industries according to the Sugar Sub-Sector Strategic Plan 2021-2025 established by (Kenya Association of Manufacturers, 2021). Agricultural production is the major economic subsector in Kenya with Sugar production being the key industry (KIPPRA, 2018). Kenya Association of Manufacturers, (2020) also established that sugar sub-sector in

Kenya is key in the both country's agricultural sector and economy with the potential to contribute to regional development, employment creation, food security, and improved livelihoods for more than eight million Kenyans. However, Kenya National Bureau of Statistics, (2019) survey demonstrates that Kenya has experienced a significant decline in milled sugar production from about 635,700 tonnes in 2015 to 491,100 tonnes in 2018. Similar findings were registered in the sugar sub-sector report by Kenya Association of Manufacturers (2020) in which production of sugar in Kenya has gradually declined, from 523,652 metric tones in 2010 to 440,935 metric tones in 2019. Kenya Association of Manufacturers (2020) Strategic Plan 2021-2025, attributes this to many challenges facing the sugar sub-sector including: high cost of production, inefficiencies across the value chain, obsolete technology, inadequate research and extension, and policy limitations. As a result, sugar importation has been increasing rapidly for the periods under review (2014, 2015, 2016, 2017 and 2018) 192.1, 227.4, 334.1, 989.6, 284.2 tones respectively (Kenya National Bureau of Statistics, 2019). This is due to the increased cost of production as established by the (Kenya National Assembly Eleventh Parliament, 2015). Also, Miwani Sugar, Muhoroni and Mumias companies have been put under receivership with Ramisi and Soin closing their operations (Kenya Association of Manufacturers, 2020)

The Kenya National Assembly Eleventh Parliament (2015) report on crisis facing the sugar industry recommended the privatization of all government-owned sugar firms in order to transform the industry into self-sustain. Miwani Sugar, Muhoroni, and Mumias companies are under receivership as indicated by (Kenya Association of Manufacturers, 2020), and the challenges faced by the sugar sub-sector include: high cost of production, inefficiencies across the value chain, obsolete technology, inadequate research, and extension and policy limitations. (Kenya Association of Manufacturers, 2020).

From the reviewed literature Kenya produces sugar at a relatively high cost, which is mostly due to incapacitation in the value chain. This not only makes the Kenyan market less competitive but also makes it a desirable destination for imports both locally and internationally Due to the reduced sugar prices caused by imports from low-cost manufacturers from other countries, local mills are unable to sell the locally produced sugar to the market at the necessary margin. Unprecedented difficulties in the sugar sector have had a significant impact on cane and sugar production. The key issues affecting the sugar subsector include, among others, high production costs, inefficiencies along the entire value chain, low productivity, severe cane shortage, weak extension support, unregulated and illegal sugar imports, weak regulatory environment, high levels of debt, lack of value-adding initiatives, poor governance, cyclical markets, outdated machinery, slow payments to cane farmers, inadequate research and extension and policy limitations. Hence, this establishes the foundation for this research in the development of a robust model of interaction among product design, LM, and operational performance practices so as to lower the cost of production, address inefficiencies across the value chain, elevate its technology and transform the sector´s policy formulation.

Lean manufacturing has been viewed by various scholars (Hernandez-Matias *et al*., 2019; Malonza, 2014; Nawanir, 2016; Seng *et al.*, 2021) as the key solution to the elimination of waste in the manufacturing systems and it boosts operational performance and can be implemented to address the challenges encountered by Sugar Firms in Kenya. Nevertheless, exciting empirical studies have not ascertained this. This study, therefore, is a stepping stone in facilitating a framework for modeling lean manufacturing practices to mitigate the eight types of waste in the production line to directly affect operational performance by boosting product quality, production efficiency, production time, and production cost. It was in this spirit that the research aimed to thoroughly investigate and analyze content and contextually the interplay among product design and lean manufacturing on operational performance of Kenyan Sugar Firms.

1.2 Statement of the Research Problem

Operational performance phenomenon continues to plague the sugar industries in Kenya, as more and more firms continue to collapse. Kenya has 12 sugar milling factories with a capacity of producing 41,000 tons of cane per day translating to a potential to produce adequate sugar that can satisfy both the domestic market and export the surplus. However, due to the decline in productivity and incapacitated value chain, the sugar subsector is not able to meet its domestic demand. Kenya has experienced a significant decline in milled sugar production from approximately 635,700 tonnes in 2015 to 491,100 tonnes in 2018. Similarly, production of sugar in Kenya has gradually been declining, from 523,652 metric tones in 2010 to 440,935 metric tones in 2019, this may be due to many challenges facing the sugar sub-sector including: the high cost of production, inefficiencies across the value chain, obsolete technology, inadequate research and extension and policy limitations. This has resulted in Miwani Sugar, Muhoroni, and Mumias companies being under receivership and Ramisi and Soin closing their operations. The key cure lies in the privatization of government-owned companies, but the Kenyan government has been reluctant to implement this. This has necessitated sugar importation which has been increasing rapidly for the periods under review (2014, 2015, 2016, 2017, and 2018) 192.1, 227.4, 334.1, 989.6, and 284.2 tones respectively. This is also because cost of sugar production in Kenya is relatively higher, mainly caused by inefficiencies throughout the entire value chain with Kenya at 870 USD/ tonne with Malawi at 350 USD/ tone, Zambia, Swaziland & Egypt at 400 USD/ tonne, Sudan at 450 USD/tonne and Brazil 300 USD/tonne. This makes the market less competitive and makes Kenya a desirable destination for imports from the region and beyond. Despite the vast contribution of the Sugar Firms to the economy, this problem of inefficient production system has not been solved and thus the Sugar Firms performance continues to spiral downward leading to the dissolution of some firms and downscaling of operations. Researchers in an attempt to find a solution to this imminent problem have established the relationship between product design and operational performance however they did not consider e-manufacturing, quality function deployment, supply chain management, and digital technologies as elements of product design and therefore information if these elements are considered as lacking and warrants investigation. Product design, lean manufacturing, and operational performance practically exist together, since lean manufacturing boosts product design by eliminating waste and consequently elevates operational performance. However, in reference to the reviewed literature, there was nonexistence of scientific prove to establish the association among the three variables, additionally, the reviewed literature show a weak association between product design and operational performance implying a moderating variable is inevitable. It is in this regard that this study purposes to demonstrate the association between product design, lean manufacturing and operational performance of Sugar Firms in Kenya.

1.3 Research Objectives

The main objective of this research was to examine the relationship between product design, lean manufacturing and operational performance of Sugar Firms in Kenya.

The following specific research objectives were constituted in the study:

i. To investigate the effect of product design on operational performance of Sugar Firms in Kenya.
ii. To evaluate the effect of lean manufacturing practices on operational performance of Sugar Firms in Kenya.
iii. To analyze the moderating effect of lean manufacturing practices on the relationship between product design and operational performance of Sugar Firms in Kenya.

1.4 Research Hypotheses

$H_{o1.}$ Product design has no significant effect on the operational performance of Sugar Firms in Kenya.

$H_{o2.}$ Lean manufacturing practices have no significant effect on the operational performance of Sugar Firms in Kenya.

H_{o3} Lean manufacturing practices have no significant moderating effect on the relationship between product design and operational performance of Sugar Firms in Kenya.

1.5 Scope of the Study

This study was centered on the association between product design, lean manufacturing and operational performance of sugar firms in Kenya. The agro-processing sector includes the sugars subsector, which is made up of 14 operational sugar firms, two under receivership and one closed its operation as indicated in Appendix IV. Out of the 14 operational sugar firms, three are government-owned sugar firms (Nzoia Sugar Company in Bungoma County and Sony Sugar Company in Migori County, Chemelil Sugar Company in Kisumu County). With West Kenya Sugar Company in Kakamega County, Soin Sugar Company in Kericho County, Kibos Sugar & Allied Industries Limited in Kisumu County, Butali Sugar Mill Limited in Kakamega County, Transmara Sugar Company in Narok County, Sukari Sugar Company in Homa-Bay County, Kwale International Sugar Company in Kwale County, Ole Pito Sugar Company in Busia County and Busia Sugar Company in Busia County being the 11 private owned sugar firms. The study was administered in Sugar firms in Kenya focusing on managers and assistant managers as units of observation. The study variables that were deployed entail product design, lean manufacturing, and operational performance.

The reason to choose to base this research on Kenyan sugar companies is that they are locally owned manufacturing companies that have been utilizing product design indicators spanning for a comparatively long period of time, sufficient to enable the development of relevant conclusions and recommendations. The time frame covered was from March 2022 to October 2023 to develop a substantive thesis.

1.6 Justification of the Study

The research may give the government more comprehension how lean manufacturing influences the interplay between product design and operational performance. An enhanced manufacturing industry has the capacity to elevate the nation's GDP and, as a result, generate increased employment opportunities. This may contribute to the development of laws and regulations aimed enhancing efficiency in the industry. Enhanced product design through the integration of LM practices may increase trade and increase export, reduce products and services production cost, and a dependable manufacturing industry.

The research may be advantageous for manufacturing companies as it can offer them a clearer insight into how operations management activities affect the performance of their businesses. They will also be better equipped with knowledge on how to deal with obstacles that may stand in the way of successful implementation of operations management activities. Operations management activities' efficiency and effectiveness may facilitate a foundation for organizational growth, enhanced productivity, decreased manufacturing costs, enhanced delivery, superior goods, and increased client satisfaction.

The research may be advantageous to the sugar companies by helping them to focus on a robust manufacturing system with a paradigm shift from loss marking to profit-making institutions and a hub for the creation of employment. In the long run, the study may assist in prioritizing resource allocation and overall performance measures in order to attain the set targets economically, efficiently, and effectively. The study may also call for a review of the production strategy to align the manufacturing system with the sector's vision and strategy, convey the overall strategic aim of the subsector, and provide a foundation for better resource allocation between strategic goals and strategic objectives to external stakeholders.

The research possibly may also be advantageous to the academic community, potentially contributing to the growing collection of literature concerning operations management activities. It might establish a structure for product design metrics which might serve as a testing ground for future research. The adoption, execution, and upgrade of operations management activities in varied cultural and corporate settings would generally benefit from the research's theoretical and practical improvements, in the context of a Kenyan setting.

This research will make a significant contribution to both the resource based view theory and transactional cost theory by confirming and refining existing principles. By delving into the strategic implications of lean manufacturing practices, the study aligns with RBV's emphasis on internal resources and capabilities as sources of competitive advantage. Simultaneously, it addresses transactional cost theory by exploring how lean manufacturing can streamline operational processes, reducing transaction costs associated with inefficiencies. The novel lean manufacturing model proposed in this study not only substantiates the theories but also provides a practical framework for organizations to enhance the interplay between product design and operational performance. This aligns with both theories, as it underscores the strategic importance of internal resources RBV and the role of transactional efficiencies in achieving organizational goals of transactional cost theory. Consequently, the research extends the theoretical understanding of these frameworks while offering actionable insights for organizational practice.

This study will further lead to affect human beings by improving efficiency and productivity, enhancing product quality, job creation, economic growth, environmental sustainability, and the advancement of knowledge and best practices. These benefits will collectively contribute to a more prosperous, sustainable, and equitable society, enhancing the overall well-being and quality of life for individuals around the world**.** If the study was not conducted it may result in inefficient processes, reduced product quality, limited job creation and economic growth, negative environmental impacts, and a lack of knowledge sharing and progress in operational practices. These effects can collectively hinder human well-being, economic prosperity, and environmental sustainability.

1.7 Conceptual Framework

The construction of the conceptual framework integrated the fundamental principles from both the transaction cost theory and the resource based view (RBV). These theories acknowledge operations management techniques as pivotal in optimizing the transformation process to enhance firm productivity through cost reduction, increased production speed, improved product quality, achieved production flexibility, and the creation of dependable products. Roble & Wanjira, (2021) recognized product design as the lead technique of operational management and seconded by Chary, (2012) who agreed that product design is the engine of all operations in any manufacturing firm. Lean manufacturing practices prompt operational performance as recognized by (Hernandez-Matias *et al*., 2019; Malonza, 2014; Nawanir, 2016 and Seng *et al*., 2021).

The study analyzed how product design affect operational performance. Rather than examining the direct relationship between the two which is responsible for the insubstantial link, the study argues that the relationship is moderated by lean manufacturing. The framework includes three sets of hypothesized relationships. The first set concerns a direct relationship between product design and operational performance. The second set concerns a direct relationship between lean manufacturing and operational performance. The third set of hypotheses speculates that the relationships between product design and operational performance are moderated by product design.

There are many product design indications that can be taken into account in determining the link to operational performance. The precise lean manufacturing indicators that were chosen for the aim of this study and that may affect operational performance are illustrated in the conceptual framework. The conceptual framework also demonstrated the measurable indicators of LM that would affect the relationship between product design and operational performance. The independent variable is product design whose indicators are e-manufacturing, quality function deployment, supply chain management, and digital technologies. This study's dependent variable is operational performance whose sub-indicators indicators are speed, quality, flexibility, product dependability, and cost. And moderating variable is lean manufacturing whose indicators include; total productive maintenance, Just-in-Time, continuous improvement, and value stream mapping.

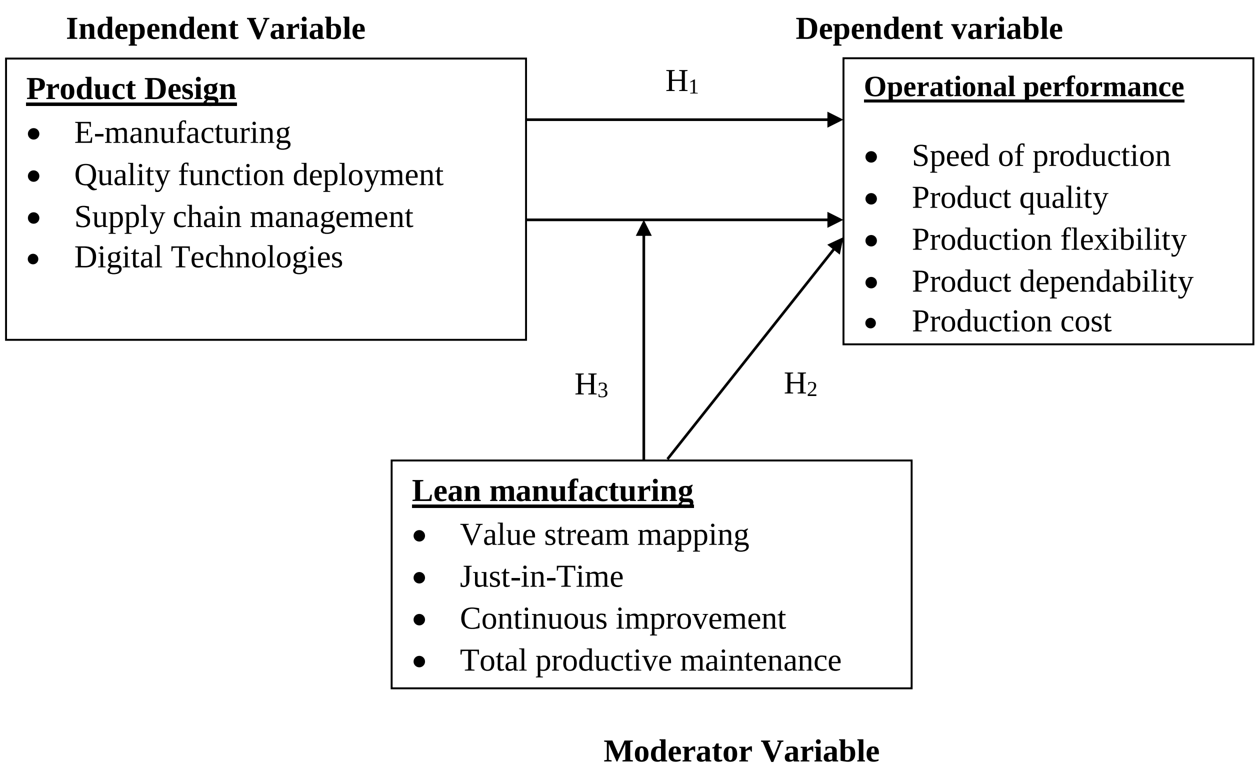


Figure 1. 2: Conceptual framework on the moderating effect of lean manufacturing on the relationship between product design and operational performance

Source: Adapted form (Reid & Sanders, 2013; Heizer *et al.*, 2017; Sayar & Er, 2019 Rocha-Lona *et al.*, 2013 ; Slack & Brandon-Jones, 2018)

CHAPTER TWO

LITERATURE REVIEW

This section establishes a theoretical framework to the research by linking, discussing the study perceptions and empirically reviewing the literature.

2.1 Theoretical Literature Review

2.1.1 Resource Based View

This research was grounded by the resource-based view theory (RBV) proposed by Barney, (1991). There is no specific theory that develops an interface between product design, lean manufacturing, and operational performance. However, RBV appreciates resources as valuable, scarce, authentic, and not substitutable and the best way to achieve long-term success. RBV is a framework that appreciates despite the adoption of product designs, product lines will experience waste, and lean manufacturing can be used to eliminate them thus elevating the operational performance of a company. As a result, this study was anchored on the RBV recommended by Barney (1991) to explain the interface between product design, lean manufacturing, and operational performance.

The main objective of RBV is to achieve a competitive edge through acquiring and adopting valuable, rare, difficult to imitate, and irreplaceable resources within a company's operations (Barney, 1991; 2002). This finding is consistently agreed by various scholars: core competencies Hamel and Prahalad (1994), the knowledge-based view (Grant, 1996), and dynamic capabilities (Helfat & Peteraf, 2003; Teece *et al*., 1997). RBV states that operational performance of a company entails the external environment and specific internal differences of the company itself (McGee, 2015). In RBV the internal differences include; characteristics, resources and capabilities (Dobbin and Baum, 2000). Barney (1991), posits the existence of resources in two categories; tangible (physical, financial, technological and organizational) assets and intangible (reputation, relationships and organizational culture) assets.

The resource based view is driven by two key assumptions about the firm's resources to demonstrate the degree of the firm's competitive edge and why some firms outperform others (Kozlenkova *et al*., 2014). The two assumptions include; as resource heterogeneity assumption and the resource immobility assumption (Mata *et al*., 1995). The resource heterogeneity assumption stipulates that certain companies are more advanced in achieving particular operations, for their exclusive resources (Helfat and Peteraf, 2003; Peteraf and Barney, 2003). The resource immobility assumption supports that variations in resources could continue. This is because of challenges in swapping resources among firms, hence giving room for diverse resources to continue over time (Barney & Hesterly, 2012).

In this research, a firm is considered to attain a competitive edge if it is adopting robust LM practices like (total productive maintenance, continuous improvement, Just-in-Time, and value stream mapping) not similarly mirrored by its competitors and they cannot emulate the advantages of the adopted practice (Barney, 1991). Barney (1991) argued that for resources or capabilities to be of importance in a company's competitive edge, they must be: valuable, reliable, inimitable, and non-substitutable. RBV recognizes that the availability of e-manufacturing resources tends to post operational performance, which is in agreement with (Barney *et al*., 2011). Further RBV postulates that if a firm's product design incorporates innovative digital technologies and is supported by efficient supply chain management, it can positively impact operational performance, which is in agreement with (Srinivasan *et al*., 2002). Product designs are rare, valuable, reliable, non-substitutable, and imperfectly imitable as they are customized within the company, hence exploiting product design will lead to sustained competitive advantage hence improved operational performance as stipulated by (Barney, 1991). A company adopting lean manufacturing practices to moderate the influence of product design on operational performance is expected to elevate the speed of production, quality products, reduced cost of production, product dependability, and flexibility in production, which is in agreement with (Peteraf & Barney, 2003). Hence, such a firm will realize more customers, predictability, higher profit margins, constancy to the company's revenue stream, and brand loyalty and may help attract additional brand associations, potential investors, and talent. Based on the literature reviewed, RBV is grounded in the philosophy that a firm's achievement is based on the notion that the capital at the company's jurisdiction influences its performance. Hence, the allocation and consumption of such resources allow the firm to utilize and can elevate its competitive advantage.

Besides that, specific practices of lean manufacturing, like value stream mapping, total productive maintenance, continuous improvement, and Just-in-Time, could enhance the utilization and effectiveness of the resources and capabilities related to product design and operational performance, further strengthening the firm's competitive advantage, this is aligned with (Barney *et al*., 2011). The RBV theory's core concept is that the combination of resources and capabilities influences a firm's performance, which is in line which (Barney & Hesterly, 2012). The Resource-Based View (RBV) provides a framework for comprehending how a company's unique and valuable internal resources, such as those related to product design, can influence and enhance operational performance indicators like speed, quality, flexibility, product dependability, and cost, by leveraging unique capabilities and optimizing resource allocation, which is in concordance with (Barney & Clark, 2007).

E-manufacturing integrates electronic technologies into production processes, improving efficiency, cost-effectiveness, and competitiveness (Helfat & Peteraf, 2003). RBV sees it as a strategic resource enhancing operational effectiveness and alignment with unique capabilities, which is in line which (Crook *et al*., 2008). Quality Function Deployment translates customer needs into design characteristics, aligning with RBV's focus on customer-centric differentiation and the utilization of distinct capabilities for sustained competitive advantage (Vorhies & Morgan, 2005). The integration of supply chain management aligns with the Resource-Based View, harnessing distinct resources to enhance supply chain efficiency, collaboration, and adaptability, thereby contributing to sustained competitive advantage (Ramaswami *et al*., 2009). And digital technologies enhance innovation, speed-to-market, and design iteration. RBV views them as dynamic capabilities that enable rapid adaptation, aligning with the theory's emphasis on unique resources and responsiveness (Srinivasan *et al*., 2002). Hence, incorporating these sub-indicators into product design aligns with RBV principles by leveraging valuable and rare resources to create competitive advantage through enhanced operational efficiency, customer-centricity, and adaptability.

Total productive maintenance focuses on minimizing equipment downtime, reducing defects, and improving overall equipment efficiency (Day, 2011). From an RBV perspective, TPM represents a distinctive capability that enhances a firm's operational performance by optimizing critical production assets (Hunt, 1997). The efficient utilization of equipment aligns with RBV's emphasis on unique, valuable, and inimitable resources contributing to sustained competitive advantage. Just-in-Time aims to reduce waste, inventory levels, and lead times by synchronizing production with demand (Barney, 1991, 2002). In the RBV framework, JIT can be seen as a valuable operational capability that enables firms to respond promptly to customer demands while minimizing wastes (Fang *et al*., 2011). JIT's focus on efficiency and flexibility resonates with RBV's focus on resources and capabilities that enable a competitive edge (Kozlenkova *et al*., 2014). Continuous improvement involves ongoing enhancements in processes and operations to achieve higher efficiency and quality (Crook *et al*., 2008). RBV aligns with this concept by emphasizing the significance of dynamic capabilities that allow firms to adapt and improve over time (Barney *et al*., 2011). The ability to continuously refine processes and foster a culture of improvement reflects RBV's emphasis on resources that provide a sustainable advantage (Barney & Hesterly, 2012). Value stream mapping analyzes end-to-end processes to identify areas of waste and inefficiency. In the context of RBV, value stream mapping represents a strategic resource that enables firms to gain insights into process optimization (Hunt, 1997). The ability to map and streamline value creation processes aligns with RBV's focus on resources that provide unique advantages and operational excellence (Barney, 1991, 2002). In summary, each sub-indicator of lean manufacturing (total productive maintenance, just-in-time, continuous improvement, and value stream mapping) aligns with RBV principles by providing unique resources and capabilities that enhance operational efficiency, flexibility, and sustainability, ultimately contributing to sustained competitive advantage.

2.1.2 Transaction Cost Theory

Transaction cost theory (TCT) was established by (Coase, 1937). The association among product design, lean manufacturing, and operational performance is not developed by any particular theory, however, based on Williamson (1979), transaction cost theory is ideal for organizational structure as it maximizes economic efficiency while reducing production costs which is in agreement with their affiliation. Williamson (1979) transaction cost theory is the cost of facilitating a company's operations. Further, according to Downey, (2022), transaction cost theory is the entire transaction costs, which include planning, decision-making, modifying plans, settling conflicts, and after-sales costs. Hence based on this, it was a suitable theory for the study as it strived to address the most important aspects influencing a company’s operational performance by recognizing the importance of product design, LM, and operational performance in the dimension of planning, decision making, modifying plans and after-sales costs in elevating firm's operational performance. This is in contrast with Young (2013) who postulated that transaction cost theory is one of the important theories that directly boost operational performance and administration of firm functions.

North (1990) contended that institutions, which are the norms that govern society are crucial in determining transaction costs. The theory holds a well-established position within the realms of disciplines in supply chain management and operations management (Grover & Malhotra, 2003). In order to reduce costs under specific exogenous circumstances, transaction cost theory recommends governance models (Schmidt & Wagner, 2019). Governance is all about coordinating the movement of commodities and services during the value transformation process. The fundamental idea behind transaction cost theory is to increase economic effectiveness in the exchange of goods and services on the market (Sun *et al*., 2020).

Transaction cost theory was significant for this study because it has an effect on the potential net return of an organization. And firms can maximize its profits from selling products or services if it´s transaction costs are low.

E-manufacturing involves the integration of electronic technologies into manufacturing processes, potentially reducing transaction costs by improving communication, coordination, and information sharing among supply chain partners (Sun *et al.*, 2020). TCT suggests that when transaction costs are high, firms may choose to internalize certain activities Williamson, (1979). E-manufacturing's potential to lower external transaction costs aligns with TCT's focus on minimizing inefficiencies in market transactions (Downey, 2022). QFD facilitates the alignment of product design with customer preferences, leading to higher quality and reduced information asymmetry (Hennart, 2010). In TCT terms, high uncertainty and information asymmetry can lead to increased transaction costs (Hobbs, 1996). QFD's ability to improve information clarity and reduce ambiguity can contribute to lowering transaction costs by enhancing the understanding of customer requirements (Cuypers *et al*., 2021). Digital technologies enable real-time information sharing, transparency, and traceability across the supply chain, potentially reducing the need for costly contractual safeguards. TCT emphasizes that transaction costs can arise from uncertainty and opportunistic behavior (Schmidt & Wagner, 2019). Digital technologies can mitigate these issues by enhancing trust and reducing the risk of opportunism, aligning with TCT's objective of minimizing transaction costs (Cuypers *et al*., 2021). Effective supply chain management aims to optimize the coordination and collaboration among supply chain partners, reducing transaction costs associated with communication, monitoring, and enforcement of contracts (Kshetri, 2018) . TCT suggests that transaction costs can be influenced by factors such as asset specificity and the frequency of transactions (Tate *et al*., 2009). Efficient supply chain management can mitigate these costs by fostering smoother interactions and reducing the need for complex contracts. In summary, each sub-indicator of product design (e-manufacturing, quality function deployment, digital technologies, and supply chain management) can be viewed through the lens of Transaction Cost Theory (Fawcett *et al*., 2006). They have the potential to lower transaction costs by improving information sharing, reducing uncertainty, enhancing coordination, and mitigating opportunistic behavior, ultimately contributing to more efficient and effective product design processes.

Total Productive Maintenance aims to minimize machine downtime and reduce maintenance costs, leading to fewer disruptions in the production process (Schmidt & Wagner, 2019). TCT emphasizes that transaction costs can arise from uncertainty and opportunistic behavior (Williamson, 1979). TPM's focus on reliability and reduced downtime can lower the risks of supply chain disruptions and unexpected costs, aligning with TCT's goal of minimizing transaction costs. Just-in-Time aims to reduce inventory and lead times by synchronizing production with demand, thereby potentially lowering storage and holding costs. TCT suggests that transaction costs can increase with higher levels of asset specificity and uncertainty (Schmidt & Wagner, 2019). JIT's focus on responsiveness and reduced inventory aligns with TCT's objective of mitigating transaction costs through efficient resource allocation.

Continuous Improvement efforts enhance process efficiency, quality, and communication among supply chain partners, potentially reducing transaction costs associated with monitoring and enforcement of contracts. TCT highlights that transaction costs can arise due to information asymmetry and the need for detailed contracts (Hennart, 2010). Continuous improvement practices can foster better communication and trust, thereby lowering transaction costs through improved coordination (Arrow, 1974). Value stream mapping analyzes processes for inefficiencies and waste, leading to streamlined operations and potentially reduced transaction costs (Schmidt & Wagner, 2019). TCT suggests that transaction costs can increase when assets are specific and contracts are complex (Christidis & Devetsikiotis, 2016). Value stream mapping's focus on process optimization can lead to better-aligned incentives and reduced need for complex contractual safeguards, aligning with TCT's goal of minimizing transaction costs (Schmidt & Wagner, 2019). In summary, each sub-indicator of lean manufacturing (total productive maintenance, just-in-time, continuous improvement, and value stream mapping) can be linked to transaction cost theory. They contribute to the reduction of transaction costs by enhancing operational efficiency, reducing uncertainty, fostering better communication, and aligning incentives, ultimately leading to more cost-effective and efficient manufacturing processes.

Speed of Production, faster production reduces lead times and response times, potentially lowering transaction costs associated with delays and uncertainties (Rosenbush, 2018). TCT emphasizes that transaction costs can arise from time-related factors such as asset specificity and opportunism (Schmidt & Wagner, 2019). Faster production aligns with TCT's objective of minimizing transaction costs by reducing risks and uncertainties related to timing (Rosenbush, 2018). Higher product quality leads to fewer defects and returns, potentially reducing transaction costs related to product failures and disputes (Hennart, 2010). TCT suggests that transaction costs can increase due to information asymmetry and uncertainty about product quality (Hennart, 2010). Ensuring high product quality aligns with TCT's goal of minimizing transaction costs by fostering trust and reducing the risks of quality-related conflicts (Carter *et al*., 2015).

Production flexibility allows for rapid adjustments to changing demand or market conditions, potentially reducing transaction costs associated with renegotiating contracts or accommodating changes (Reuer *et al*., 2002). TCT highlights that transaction costs can arise from uncertainty and the need for contractual safeguards (Schmidt & Wagner, 2019). Production flexibility aligns with TCT's objective of minimizing transaction costs by enabling adaptive responses and reducing the need for extensive contractual specifications (Hennart, 2010). Product dependability contribute to reliable supply chains and fewer disruptions, potentially reducing transaction costs related to supply chain uncertainties (Fawcett *et al*., 2006). TCT suggests that transaction costs can increase with uncertainty and asset specificity (Rosenbush, 2018). Product dependability aligns with TCT's goal of minimizing transaction costs by enhancing predictability and reducing the risks of supply chain disruptions (Schmidt & Wagner, 2019). Lower production costs contribute to higher efficiency and cost-effectiveness, potentially reducing transaction costs related to overpricing or disputes. TCT emphasizes that transaction costs can arise from excessive contracting and monitoring efforts. Lowering production costs aligns with TCT's objective of minimizing transaction costs by reducing the need for detailed contractual safeguards and continuous monitoring (Carter *et al*., 2015). In summary, each sub-indicator of operational performance (speed of production, product quality, production flexibility, product dependability, and production cost) can be linked to Transaction Cost Theory. They contribute to the reduction of transaction costs by enhancing efficiency, reducing uncertainties, fostering trust, and aligning incentives, ultimately leading to more cost-effective and streamlined operational processes.

2.1.3 Unification of Resource-Based View and Transactional Cost Theory

In unifying these two theories, one approach is to consider the role of resources in managing transaction costs. Specifically, a company's resources and capabilities may influence contracting costs and the choice of the company's structure (Hansen & Schütter, 2009). Another approach to unifying the two theories is to consider the role of transaction costs in shaping the firm's resource allocation decisions (Lazzari *et al*., 2014). Specifically, the costs of transacting with external parties can impact the firm's decisions about which resources and capabilities to develop internally versus which to acquire through external partnerships or acquisitions.

The amalgamation of resource based view and transaction cost creates a robust analytical framework for comprehensively exploring the intricate interplay between product design, lean manufacturing, and operational performance. RBV, with its focus on harnessing unique resources and capabilities, serves as the primary lens through which this study examines how strategic alignment of product design practices and lean manufacturing techniques can yield sustainable competitive advantage. RBV's emphasis on distinct attributes within both product design, like e-manufacturing, quality function deployment, and digital technologies, and lean manufacturing, including total productive maintenance, just-in-time, continuous improvement, and value stream mapping, resonates with the study's objective of understanding how these practices enhance operational efficiency and customer-centricity.

RBV was the lead theory for this scholarly investigation. The choice of RBV as the lead theory stems from its emphasis on the strategic utilization of internal resources and capabilities to gain a competitive edge (Dutta *et al*., 1999) . While Transaction Cost Theory offers valuable insights into cost considerations and contractual aspects, RBV's central role lies in its ability to guide the exploration of how firms strategically integrate product design and lean manufacturing within their unique resource portfolio. By placing RBV at the forefront, this study seeks to unravel the strategic implications of these practices, highlighting how they contribute to sustained operational excellence, improved performance, and enhanced market positioning.

In summary, the RBV and TCT can be unified by considering the interplay between a firm's internal resources and its external transactional environment. By leveraging its resources to manage transaction costs and strategically allocating resources to minimize transaction costs, a firm can achieve sustained competitive advantage.

2.1.4 The Concept of Product Design

(Bloch, 2011; Bocken *et al*., 2016; Bourgeois-Bougrine *et al*., 2017; Demirbilek & Sener, 2003; Gani, 2004; Nwokah *et al*., 2009; Westerberg & Subrahmanian, 2000) postulated that product design can hardly be anchored from a mono-disciplinary perspective as it cuts across business, science, IT, and engineering. Product design exerts a significant influence on the unique characteristics and features of the firm's products (Homburg *et al*., 2015). To have a solid understanding of product design it will be prudent to give its definition.

A consensus on the definition of product design has not been universally established Bloch (2011), this variation arises due to large product categories (Homburg *et al*., 2015). Reid and

Sanders, (2013), defined product design as the procedure of modeling the product characteristics; the materials it is made of, its performance standards appearance, and its dimensions and tolerances. Product design may also be defined as a logical process involving ideas or generation of concepts, development of concepts and evaluation, manufacturing, and testing of a product or service (Blomé, 2015). Product design is the practice of market blend, management of a product, industrial design, and engineering (Mazumdar, 2001). Product design is the process of perceiving, engineering, and comparing products that address customer expectations. Roper *et al*. (2016) defined product design as the core starting point in support of advancement and architecture of new goods. Product design is a multifaceted process for solving problems that are integral in the architecting of new products (Bleda *et al*., 2021).

Product design is a primary function in the product transformation process (Perks *et al*., 2005). As a result product design influences consumer preferences positively (Kumar & Noble, (2016) by involving them in the product design process (Ravasi & Stigliani, 2012). Product design ensures that the products produced satisfy the customer's needs (Reid & Sanders, 2013). Manufacturing companies design, develop and introduce new products as a strategy to survive and grow (Anil Kumar & Suresh, 2008). As a result product design not only entails usefulness and appearance, nonetheless, also entails resources and choice of supplier, product design management, and prototype development (Utterback, 2006).

Inappropriate product design may lead to loss of market share, bad reputation, and serious damage to profit margins. This has made production lines to be more volatile with high production costs and increased waste over time. In order to address such eventualities, the adoption of a robust product design ensures efficiency to produce quality products that meet customer requirements and gain a competitive edge. Nevertheless, product designs may result in both positive and negative outcomes. Product design is anchored on three dimensions, function, form, and ergonomics (Jindal *et al*., 2016).

However, there are no empirically, substantive, and unison product design dimensions resulting in different classifications in literature. Srinivasan *et al*., (2012) classified the three dimensions as; function, form, and meaning viewing the dimensions as significance and memorial connotations around the products shared by consumers. With the same spirit, Homburg *et al*., (2015) modeled product design into three distinct aspects of; symbolic, form, and functionality dimensions, in assuming ergonomics unambiguously within the realm of the dimension of functionality. According to them, product design dimensions are the self-image linked to the consumers. Symbolism and meaning dimensions are other requirements of the product for individual customer manifestation and are realized as an outcome after consuming the product (Keller, 1993). In the view that product design and associated dimensions can change the product's symbolism or meaning (Rubera, 2015). The following metrics were used in this study to evaluate product design: e-manufacturing proposed by Reid and Sanders, (2013) supply chain management and quality function deployment proposed by Heizer *et al*. (2017); and digital technologies proposed by Sayar and Er, (2019).

2.1.4.1 E-Manufacturing

Reid and Sanders (2013) e-manufacturing also known as web-based environment/ computer-aided design/ computer-integrated manufacturing facilitates customers, purchasers, and designers to group information into segments and make judgments in real time to boost product and process design. Wu *et al*. (2016), postulated that with the advent of a web-based environment, manufacturing firms have been able to create a link with their stakeholders by developing a robust feedback framework resulting in numerous opportunities for business collaboration. Heizer *et al*. (2017) defined computer-aided design (CAD) as the process of creating engineering documentation and designing items interactively using computers. Bi and Wang (2020) defined e-manufacturing as a computer-based integration system involving every component used in a product's manufacturing system.

According to Bi and Wang (2020) computer-integrated manufacturing (CIM) system is made up of elements including computer-aided process planning, robotics, database technology, computer-aided production control, computer-aided design, process and adaptive control, expert systems, information flow, and automated inspection techniques. Patrikalakis and Maekawa, (2009) argued that using a single database, all of these elements operate as a union so as to adopt a robust product design in the manufacturing system.

2.1.4.2 Quality Function Deployment

Heizer *et al*. (2017) referred to quality function development as a process of configuring what will satisfy the customer and then incorporating that knowledge into the target design. Erdil and Arani, (2018) quality function deployment enhances key quality features of a product design and sales rates by addressing areas of perfection and transforming them into quantifiable product attributes. It results in decreased initial costs, shortened improvement times, and improved standards of new product (Evans & Lindsay, 2015). Mitra, (2016) mainly quality function development (QDF) is applied in design-related projects, and manufacturing firms use QFD for product design and development.

Murali *et al*. (2016) opined that implementation of QFD has significant outcomes; cost reductions for new product development, minimizes the rework and design changes, and mitigates the risk of failure in the manufacturing system. Ozalp *et al*. (2020) rated quality function deployment as the best practice for product design. Frizziero *et al*. (2018) postulated that by selecting and specifying a criteria that can be qualitatively contested, QFD achieves product design. International Organization for Standardization (2015) in its ISO 16355 standard, view QFD as a technique that ensures consumers' or investors' gratification and worth of new and current products by including the expectations that are most important to them from all levels and diverse expectations.

2.1.4.3 Supply Chain Management

American Production and Inventory Control Society Dictionary, (2016) characterizes supply chain management as the production for value, the development of a framework for competitiveness, the influence of distribution, the fusing of supply and demand, and the mapping of performance on a worldwide scale. According to Heizer *et al*. (2017), supply chain management (SCM) reviews product design by coordinating all supply chain linkages, from input to output in the manufacturing system to considering stakeholder interests. Reid and Sanders, (2013) argued that supply chain management is an essential corporate function responsible for orchestrating and overseeing all activities throughout the supply chain, linking stakeholders through a robust product design. Desai & Rai, (2016) SCM integrations harmonizes crucial business operations spanning from end users to original suppliers, by providing valuable information to consumers and other stakeholders. Sinaga *et al*. (2021) supply chain management seeks to reduce operating expenses that arise throughout the chain, guarantee that product quality is maintained, and ensure that products are available and services are delivered quickly enough to be valuable to customers.

2.1.4.4 Digital Technologies

Sayar and Er (2019) advances in digital technologies necessitate a reevaluation of producers' approaches of product design by involves leveraging customer data to structure and mold expectations and performance objectives, permitting adjustments to facilitate the robust provision of service, and inform various stakeholders in the value chain about the product's history and present state. Goduscheit and Faullant, (2018) adoption of digital technology is a crucial basis for manufacturing companies to launch innovative services, according to research from other industries to shape their product designs. Product design tactics and measures have benefited from technology's ability to ensure business continuity by establishing links that ensure seamless operation of the company's operations (Margherita *et al*., 2021).

Blichfeldt and Faullant (2021) digital technologies are a driver of product improvement as well as a pillar for manufacturing companies introducing new services. Prause, (2019) the short-term adoption of innovative technology is also accelerated by market uncertainty, hence, boosting a firm’s operational performance in terms of innovation. Paiola and Gebauer (2020) these technological advancements give businesses avenues to quickly react to the changes brought on by the COVID-19 pandemic. Ostrom *et al*. (2015) postulated that developments in digital technology facilitate the growth of innovative services with varied stakeholder benefits.

2.1.5 The Concept of Lean Manufacturing

Manufacturing companies are embracing the adoption of lean manufacturing practices (Abolhassani *et al*., 2016). This is due to the expectation that implementing lean manufacturing leads to a notable improvement in a firm’s operational performance, achieved through minimizing waste within the production system (Shi *et al*., 2019). Lean manufacturing practices are therefore adopted by manufacturing companies for the purpose of elevating them above their rivals by streamlining their production operations (Zahraee *et al*., 2020). Similarly, Lazai *et al*., (2020) postulated that utilization of LM practices may cause a substantial impact on a company's performance as it analyzes its production process by ensuring efficiency and lowering the cost of production. Additionally, Lean manufacturing prioritizes meeting customer requests while sacrificing demand dynamics in order to provide goods and services at the most affordable cost (Bhamu & Sangwan, 2014).

To achieve a seamless supply chain, lean manufacturing is characterized as a logically organized production system with the ability to detect and remove waste through regular and continuous improvement in the manufacturing system (Silva, 2012). Anything that does not bring value to any activity is considered waste (Suhardi *et al*., 2019). Womack and Jones, (2003) outlined 8 types of waste: inventory waste, overproduction waste, correction waste, motion waste, knowledge waste, waiting waste, unnecessary transportation waste, and over-processing waste. Rocha-Lona *et al*. (2013) defined four key lean manufacturing practices in use today; Just-in-Time, total productive maintenance, value stream mapping and continuous improvement.

Lean manufacturing practices are driven by a focus on the mitigation of waste to maximize the value of the product or service (Sundar *et al*., 2014). Lean manufacturing matrix is flexible and a variety of performance indicators must be adopted (Martínez-Jurado & Moyano-Fuentes, 2014). There are various definitions of LM anchored in the framework of the product line guided by the product design. Felizzola Jiménez and Luna Amaya (2014) defined LM as techniques for improving the quality of production by optimizing customer needs and through review of production lines by producing outputs with fewer resources. Johan and Soediantono (2022) also lean manufacturing a production technique that ensures an effective transformation process by utilizing available resources to attain economic value for customers without any waste. Similarly, Castillo, (2022) defined LM as an approach used to eliminate waste while adopting minimal effort to maximize customer satisfaction.

Salonitis and Tsinopoulos (2016) established that core objective of lean manufacturing is to minimize or abolish waste within the production system by identifying and removing redundant activities. Jasti and Kodali (2014) opined that LM is a widely acknowledged management approach that results in delivering quality and value to customers through elimination of waste within the manufacturing system. Waste is any operation that does not add value to a consumer (Lacerda *et al*., 2016). Patidar *et al*., (2017) termed waste as undertakings that directly and indirectly add expenditure and increases the transformation period and storage. Productivity may be increased through eliminating waste, by reducing production costs hence increasing the market opportunities (Ikatrinasari & Kosasih, 2021). There are eight categories of waste in the production line namely; waiting, defects, transportation, excess processing, inventories, overproduction, non-utilized talent, and motion (Fauzi *et al*., 2022).

Elevating additional value for the customer by decreasing and/or abolishing any operation that fails to contribute value throughout the product value chain is an essential principle fundamental tenet of lean manufacturing (Sanders *et al*., 2016). Waste in a production line can decrease value for the customer, by increasing or introducing any procedure which fails to add value to the production line (Czarnecka *et al*., 2017). Waste has become a problem as it negatively and immensely affects a company's operational performance (Khalfallah & Lakhal, 2020). Hence, defining a waste mitigation strategy in the production line is a major requirement for addressing, eliminating, or mitigating the waste before the negatively affects operational performance (Fauzi *et al.*, 2022). Various studies have agreed with the paradigm that adoption of lean manufacturing practices results to; improved efficiency, waste reduction, and increased productivity (Hernandez-Matias *et al*., 2019; Johan & Soediantono, 2022). The following LM principles recommended by Rocha-Lona *et al*., (2013) were adopted to constitute LM metrics;

value stream mapping, just-in-time, total productive maintenance, and continuous improvement.

2.1.5.1 Just-in-Time

Dange *et al*. (2014) postulated that because of the success associated with the implementation of JIT in the Japanese manufacturing industry, it has become a very popular operation model. Romero and Arce (2017) the primary goal of JIT is to systematically eliminate waste and activities that do not add value to the manufacturing system. Rahmani and Nayebi (2014) argued that manufacturing company's material flow is monitored by a JIT system to reduce the amount of produced waste. Similarly finding were registered by Masudin and Kamara (2018) who postulated that many manufacturing companies have adopted JIT to enhance organizational performance in various dimensions.

Phan *et al*. (2019) constant pursuant of the modest way to make manufacturing more productive is the philosophy spearheading the adoption of JIT that ensures continuity by making performance processes more fruitful. The primary objective of just-in-time is to produce goods and services with minimal waste (Shahad, 2020). JIT enhances; better returns on investments due to lower carrying costs, constant delivery of high-quality goods, and enhanced collaboration that helped to improve supplier-customer relations (Kinyua, 2015).

2.1.5.2 Total Productive Maintenance

Xiang and Chin (2021) defined TPM as techniques of upholding worker initiative by lowering failure rates and preserving equipment efficiency. TPM is adversely used for machine maintenance in industrial firms to minimize losses in manufacturing, extend machine lifespan, and guarantee optimal use of machinery (Majumdar, 2017), decreases accident incidence, and boosts staff confidence (Sharma *et al*., 2018). Joshi and Bhatt (2018) established that TPM implementation significantly boosts success rate. Additional advantages of TPM implementation include; ensuring the productiveness and effectiveness of employees (Ali, 2019), reduction of overtime and absenteeism (Li, 2013) decreased turnover time (Bon & Lim, 2015), enhanced self-assurance (Maran *et al*., 2016) and facilitation of conservation capability (Singh & Ahuja, 2015).

TPM is a comprehensive approach, which aims at reducing loss and waste (Hooi & Leong, 2017). In 1971, the Japanese pioneered and refined the concept of Total Productive Maintenance when addressing maintenance and problem-solving in manufacturing companies (Ighravwe and Oke, 2020). For instance, it aims at minimizing waste and maximizing output through lower-cost of production and higher-quality output (Habidin *et al*., 2019). Likewise, TPM makes equipment operating conditions better, makes it possible to reach takt time at the maximum equipment efficiency, and keeps the machine running at its best in terms of performance and dependability. Agustiady and Cudney, (2018) postulated that to effectively implement and utilize TPM in a Manufacturing firm, it should be organized in in three steps, define, implement and sustain.

2.1.5.3 Value Steam Mapping

The main purpose of developing value stream mapping is to pinpoint the waste-producing segments in the production system and facilitate the creation of potential solutions to minimize and eliminate waste (Schoeman *et al*., 2020). VSM is a principle of lean manufacturing that may be logically adopted to integrate and measure all operations in a manufacturing system to realize a firm's competitive edge by suppressing errors, losses, and lead time as well as improving value-added activities (Forno *et al*., 2014).

Womack and Jones (2003) categorized VSM into three activities in the manufacturing system: necessary but non-value-added (NNVA), unnecessary (NVA), and value-added (VA), non-value-added. Value stream mapping's purpose is to enhance value-creating time by lowering NNVA operations, removing NVA activities promptly, and streamlining the movement of goods, feedback, and cash (Qin & Liu, 2022). Alaya (2016) indicated that universally VSM is among the key parameters in the adoption of LM among manufacturing firms. Similarly, Andreadis *et al*.,(2017) argued that the adoption of lean manufacturing practices will not be complete without incorporating value stream mapping as the lead principle. Sharma and Virmani (2020) VSM enables managers to define waste in the manufacturing line and the possible solutions for eliminating the waste in the future.

2.1.5.4 Continuous Improvement

Singh and Singh (2015) defined CI as a process that involves everyone in the firm and aims to reduce waste in all organizational systems and processes. Kayanda, (2016) CI enhances the quality of the products, services, and production processes. According to Stålberg (2014), continuous improvement is a process for making improvements that are ongoing, unending, and encompasses a variety of changes, from little adjustments to more significant ones. Quesada-Pineda and Madrigal, (2013) viewed continuous improvement as an avenue for innovation as it fosters a learning environment where individuals can be creative while also aligning their goals with those of the organization.

According to Holtskog (2013), continuous improvement is a long-term management-driven approach if incorporated into a company it can boot its manufacturing system and can support continued competitiveness in international markets. Melnik (2016) stipulated that CI is a key manufacturing technique for firms to enable them to attain a sustainable competitive edge. Sraun and Singh, (2017) postulated that technical implementation of CI may improve manufacturing efficiency and effectiveness. Arruda *et al*., (2015) implementation of continuous improvement by manufacturing companies demonstrates their desire to retain a high level of competitiveness in a market that is becoming more unstable.

2.1.6 The Concept of Operational Performance

Operational performance is the strategic scope a company opts to adopt to attain a competitive edge (Chavez *et al*., 2015). Measurement of the manufacturing systems operational performance elevates manufacturing companies economically and sustainably. Hence the study adopted five standalone dimensions: speed of production, product quality, flexibility, dependability, and cost of production to measure operational performance proposed by (Slack & Brandon-Jones, 2018). Empirically operational performance is based on performance in general terms (Buttar, 2011) rather than competitors-centered (Luu, 2017). Hence this study's operational performance is driven by the firm's competitive edge. Slack and Brandon-Jones (2018) postulated that speed of production is the time taken among customers placing an order for goods and services and the customer getting them in as ordered. Kogel and Jauergui (2016) stated that speed of production is dictated by the custom demand rate. Also, Njenga (2018) defined speed of production as the rate at which customer needs and orders are responded to by a company.

Adi and Anik (2018) defines product quality as the combination of a product's characteristics and qualities that depend on its capacity to fulfill explicit or implicit customer needs. Oghojafor *et al*. (2014) observe that better product quality tends to promote consumer loyalty. Djumarno and Djamaluddin (2018) state that customers will be pleased and think that a product is of good or even excellent quality if it satisfies their perceived expectations. According to Chen and Gayle (2019) argued that quality of a product is the general feature of characteristics of a product emanating from engineering, production, marketing, and maintenance approaches that defines product functionality and attaining customer desires, it involves everything that a producer has to offer by satisfying customers' expectations.

Slack and Brandon-Jones (2018) argued that flexibility is the capacity to change or adjust operations to deal with unforeseen occurrences, provide individualized care for stakeholders, or launch new goods or services. According to Reid and Sanders (2013) affirmed that flexibility involves a manufacturing company’s potential to quickly adjust to variations particularly consumer wants and expectations, and can be a winning approach in a company's environment. Also, flexibility was viewed as a company’s ability to quickly adjust to dynamic customer needs. Lasi *et al*. (2014) observed that due to increasing global rivalry, manufacturing organizations' flexibility and resource efficiency have come under pressure to meet customer demand and maintain their competitiveness.

Slack and Brandon-Jones (2018) affirmed that product dependability also known as product delivery encompasses the capacity to execute tasks promptly while adhering to delivery commitments made to customers. (Anitah, 2019) product dependability is the ability of a company to deliver products at the right time. Rasi *et al*. (2015) postulated that product dependability aims at the delivery of products in a timely manner and the time taken to respond to recommended changes.

Adam *et al*., (2022) defined production cost as the cost a firm incurs during the refining of goods or provisions of services, entailing of direct and indirect expenses. According to Case *et al*. (2016) production cost is determined by a number of elements, which include; the technologies available and the costs and quantities of the firm's inputs (labor, raw materials, capital, energy, and so on). Slack and Brandon-Jones (2018) products and services are produced at a price enabling them to just be valued in the market fairly whereas providing the firm with profit and guaranteeing the satisfaction of customers and the firm’s competitiveness.

2.2 Empirical Literature Review

This subsection conducts a systematic examination of prior literature while directed by the goals of the investigation. The systematic literature review helped to identify a number of research gaps.

2.2.1 Product Design and Operational Performance

Objective one soughed to examine how product design influences the performance of Kenyan sugar companies' operations. Several previous research studies on product design were reviewed to facilitate the establishment of the research.

Gao *et al*. 1) conducted a study on the role of social media in an inspirational approach to product design and designer performance in Pakistan. This research investigates the impact of enterprise social media and public social media on the development of novelty-focused and efficiency-focused product designs, and how these design approaches contribute to the performance of designers. The research was centered on 16 companies in Pakistan. The study sampled 419 employees from 16 companies, and registered 295 responses, representing a 70% response rate. While investing the effect of efficiency-focused product design on designer performance, the study justified a positive and significance association, however, the relationship established was weak, as demonstrated by ($\beta = 0.27$, $p < 0.001$). Further, the study did not use any moderating variable to measure the extent to which product design can impact a firm's operational performance.

Ahmad *et al*. (2018) carried out a study on the impact of product design and process design on new product performance in manufacturing industry in Malaysia. The findings established a notable and positive correlation between product design and product process design in relation to new product performance. The study further revealed an outstanding relationship between product design and organizational performance ($r = 0.570$, $p < 0.05$). The research adopted a questionnaire-based method to gather views from 400 respondents and out of which only 80 responded representing 20% of the target population. This is a small response rate (20%) meaning that the study suffered 80% nonresponse biasness of hence commemorating to biased conclusions.

A study was carried out by Coudounaris (2018) on the mediation of product design and moderating effects of reference groups in the context of country of origin effect of a luxury brand in Tartu, Estonia. The study adopted product design as a moderator and antecedent factors as the independent variables with luxury brand as the dependent variable. The study was conducted through an online survey from a sample of 3848 respondents and recorded 275 responses out of the online survey. The findings revealed that antecedent factors and product experience are partially mediated by product design on the demand for luxury brand with $\beta = 0.72$, $t = 16.29$, $p = 0.0000$, and adjusted R^2=00.521. However, the study adopted an online survey which is prone to non-response bias, as survey fraud is eminent when conducting online surveys. The respondent margin was very small compared to the sample population, hence may prevent the findings from being extrapolated.

Kwaku and Fan (2020) conducted a study on the effect of good product design and packaging on market value and the performance of agricultural products in the Ghanaian market. 250 agricultural product marketers, processors, and consumers from 25 countries were sampled using a survey. The study participants were selected using simple random sampling and purposive sampling techniques. The research recognized that agricultural products' performance in the Ghanaian market was positively impacted by product design, with a correlation coefficient of 0.736. However, the study did not apply e-manufacturing, quality function deployment, supply chain management, and digital technologies which are key indicators that measure product design. The possibility of bias in sample selection exists when the purposive sampling technique is used.

Bagshaw (2017) while looking at the process and product design: production efficiency of manufacturing firms in Rivers State, Nigeria observed that product design and process design are considerable and positively affect the efficiency of production with a correlation coefficient of 0.824. The research was based on a sample of 28 production managers of manufacturing companies based Nigeria. The researcher focused on a confined geographical area which might limit the applicability of the study's findings to a broader context. The study did not define the appropriate survey design to adopt du ring data collection given that the researcher was studying the entire and small target population.

Putri and Rofiq (2020) conducted a study to establish the effect between product design and iconic product in attractiveness on cultural identity with buying decision (study on Batik Consumer Malang) in Egypt. With a target population of 166 consumers of Malangn bkit the research adopted an explanatory research design. The study established that the quality of batik with design product has a significant effect on consumer decision to buy it with a coefficient correlation of .882. Conversely, the research did not take into account e-manufacturing, quality function deployment, supply chain management, and digital technologies which are important metrics for evaluating product design.

Roble and Wanjira (2021) carried out a study on the effects of product design on the performance of commercial banks in Garissa County, Kenya. This research embraced census to collect data from 82 employees of 4 Commercial Banks in Garissa. The study adopted unique products, reliability, and integration as indicators to measure product design. The researchers revealed a definite substantial correlation between product design and operational performance signified by an adjusted R^2 value of 0.772 (77.2%) expounded by the three independent indicators of product design that were under study. This study did not use any moderating variable to measure the extent to which product design can impact operational performance. The study was based on the commercial banks in Garissa County and did not factor in other regions with more stabilized commercial banks in contrast to the growing county. Also, the study was focused on unique product, reliability, and integration as indicators to measure product design and did not address e-manufacturing, quality function deployment, supply chain management, and digital technologies which are key indicators that measure product design. The study focused on a confined geographical area which might limit the applicability of the study's findings to a broader context.

Kariuki (2016) conducted a study on the production system design and operational performance of steel manufacturers in Kenya. The research was centered on 20 steel manufacturing firms in Kenya. The study population entailed departmental managers of maintenance, production, and plant/operations departments yielding a combined total of 60 respondents. The study acknowledged a substantial influence of production system design on the operational performance of an organization, evidenced by a correlation coefficient of 0.784. However, this study did not use any moderating variable to measure the extent to which product design can impact a firm's operational performance.

The reviewed studies ignored adopting a lean manufacturing as moderating variable to measure the extent to which product design can impact operational performance. Besides that, they were based on a small case study hence they may make the findings of the study not generalizable. Also, the review studies did not address e-manufacturing, quality function deployment, supply chain management, and digital technologies which are key indicators that measure product design. Finally, the reviewed studies did not take Sugar Subsector as a case study hence forming a basis for this study.

The outcomes of this research are aligned with the results of a prior investigation carried out by (Ahmad *et al*., 2018; Bagshaw, 2017; Gao *et al*., 2021; Kariuki, 2016; Kwaku & Fan, 2020; Roble & Wanjira, 2021) confirmed the existence of a positive correlation between product design and operational performance. However, the findings of previous studies had their own weakness which do not align with the findings of the current study. A study conducted by Kariuki (2016), showed a strong relationship with an R-squared value of 0.767 ($p = 0.002$). Nevertheless, it did not include a moderator variable to investigate how a moderator might impact this relationship. Besides that, a study conducted by Gao *et al*., (2021) demonstrated a weak association of ($\beta = 0.27$, $p < 0.001$) as compared to the present research which demonstrated a more positive and significant connection between variables. The research by Ahmad *et al*. (2018) adopted a questionnaire method to gather data from 400 respondents and out of which only 80 responded representing 20% of the target population. This is a small response rate (20%) meaning that the study suffered 80% nonresponse biasness of hence commemorating to biased conclusions, further, the study registered a weaker association ($r = 0.570$, $p < 0.05$). The study by Bagshaw (2017) was based on a sample of 28 production managers of manufacturing firms in Nigeria. The research focused on a confined geographical area which might limit the applicability of the study's findings to a broader context. Further, Bagshaw (2017) established a weak association of (PV=0.000<0.05, t-cal=5.559>t-tab (0.05, 27)=2.05) as compared with the current study's result (β=0.742, p=0.000) which demonstrates a more significant and interpretable relationship between variables, supported by a strong effect size and a highly significant p-value.

2.2.2 Lean Manufacturing and Operational Performance

The second objective sought to evaluate the effect of lean manufacturing and operational performance of Sugar Firms in Kenya. To identify gaps relevant to this objective, various previous studies were examined.

Hernandez-Matias *et al*. (2019) carried out a study on lean manufacturing and operational performance interrelationships between human-related lean practices focusing on lean production managers and frontline supervisors of 202 Spanish companies. They established that lean manufacturing helps managers to establish a pattern that a firm may adopt in human-related lean practices to positively implement LM so as to boost operational performance. The research was based on a mixed research design. However, the study adopted web surveys which are prone to survey fraud being the key weakness of online surveys, hence culminating in biased conclusions. Also, they did not adopt lean manufacturing indicators like continuous improvement, Just-in-Time, total productive maintenance, and value stream mapping to measure it instead it was limited to applied human-related lean practices. Finally, the study also was entirely based on human-related lean practices and did not review the production system which is a key unit of interest in matters of lean manufacturing.

Seng *et al*. (2021) while studying Industry 4.0 and lean manufacturing practices: an approach to enhance operational performance in Singapore's manufacturing sector, a positive association was established by the researchers between LM and operational performance. A total of 51 companies were sampled giving attention to the integration of lean and industry relation 4.0. The study utilized employee training, continuous improvement, top management leadership, supplier partnership, small group problems, customer involvement and industry relation 4.0 as sub-indicators of lean manufacturing. However, the study adopted a survey method that does not encourage respondents to provide accurate, honest judgment.

Nawanir (2016) while studying the effect of lean manufacturing on operations performance and business performance in manufacturing companies in Indonesia involving 174 large manufacturing companies focused on the functions of LM. The research concluded that lean manufacturing practices are significantly associated and they are interdependent. Besides that, study outcomes indicated that lean manufacturing practices ought to be adopted holistically, as they jointly support and supplement each other. Also, the study established that Lean manufacturing is positively correlated with a firm's operational performance. The study adopted a purposive sampling technique. However, it is not appropriate for gathering data from a large population and hence may result in sampling biasness and invalid research outcomes.

Malonza (2014) employed the theory of Constraints to explore the effect of lean manufacturing on operational performance of Mumias Sugar Company Limited, Kenya. The study adopted descriptive approach and utilized a case study centered on Mumias Sugar. The study indicated a notable correlation between LM and operational performance. It also indicated that implementation of lean manufacturing practices may result to: improved standardization of processes, improved efficiencies, and housekeeping of plant. The case study applied for this study was very relatively small hence the research outcome acquired might not be appropriate to be generalizable.

Kunyoria (2018) conducted a study on the effect of lean manufacturing on organizational performance taking a case of South Nyanza Sugar Company, Awendo Kenya. The study adopted a correlational research design. The study sampled 78 respondents from different departments in the Sugar Company, Awendo Kenya using a stratified random sampling method. Based on the findings, the indicators of lean manufacturing were based on technology adoption, intellectual knowledge, and elimination of waste. The study indicated a notable correlation between LM and organizational performance. However, the case study was too small to be used for the purpose of generalization.

Buer *et al.* (2021) conducted a study to assess the complementary effect of lean manufacturing and digitalization on operational performance in Norway. The study was based on an online survey from a sample of 212 Norwegian manufacturing companies and recoded 76 responses from the online survey. The findings revealed that for manufacturing firms to fully benefit from new technologies and turn them into better operational performance, lean manufacturing remains pertinent rather a more significant strategy to adopt. However, the study adopted an online survey which is prone to non-response bias, as survey fraud is eminent when conducting online surveys. The respondent margin was very small compared to the sample population, hence may prevent the findings from being extrapolated.

Nawanir (2016) carried out a study on the effect of lean manufacturing on operations performance and business performance in manufacturing companies in Indonesia. The study adopted a mail-based survey to collect data from 1000 respondents. The study established that lean manufacturing is positively associated with operations and business performance. The study, however, adopted an online survey which is prone to non-response bias, as survey fraud is eminent when conducting online surveys. The study did not utilize: value stream mapping, continuous improvement, total productive maintenance and Just-in-Time which are the main principles to measure lean manufacturing.

Hernandez-Matias *et al*. (2019); Seng *et al*. (2021); Nawanir (2016); Malonza (2014); Kunyoria (2018); Buer *et al.* (2021); and Nawanir (2016) conducted studies to examine the effect of lean manufacturing on operational performance. Their findings postulated that lean manufacturing was positively linked to operational performance. However, Hernandez-Matias *et al*. (2019); Buer *et al.* (2021); and Nawanir (2016) in their studies they adopted web surveys which may culminate in biased conclusions. Seng *et al*. (2021) in their study to investigate industry 4.0 and lean manufacturing practices: an approach to enhance operational performance in Singapore's manufacturing sector adopted a survey method that does not encourage respondents to provide accurate, honest judgment. Malonza (2014) and Kunyoria (2018) conducted their studies on the effect of lean manufacturing on operational performance of Mumias Sugar Company Limited, Kenya, and South Nyanza Sugar Company, Awendo Kenya respectively. However, the case study adopted for this study was relatively small hence the research outcomes might not be generalizable. All the reviewed studies did not adopt principles of lean manufacturing: value stream mapping, continuous improvement, Just-in-Time, and total productive maintenance proposed by Rocha-Lona *et al*. (2013) which additionally will affect operational performance and determine its moderation effect on the association among product design and operational performance. Finally only two of the reviewed studies (Malonza, 2014) & Kunyoria, 2018) did take Sugar Subsector as a case study hence forming a basis for this study in this subsector and further they were anchored on relatively small case studies. Consequently, the case studies of both studies was too small to be used for the purpose of generalization. Moreover, (Kunyoria, 2018) study result (β=0.672, p = 0.037) indicates a significant relationship as well, but the proximity of the p-value to the significance threshold suggests a slightly weaker level of confidence.

It is worth noting that the prior research approaches have, further, been criticized. Buer *et al*. (2021); Hernandez-Matias *et al*. (2019); Nawanir (2016) utilized web surveys, which might introduce bias and affect the accuracy of their conclusions. The study by Buer *et al*. (2021) result (β = 0.444, p = 0.005) demonstrated significance, but the higher p-value suggests a slightly less confident level of significance. Similarly, Seng *et al*. (2021) study results (R square is 0.644, Durbin-Watson is 2.312) provided an R-squared value that indicated meaningful explained variance but did not offer insight into the statistical significance of the relationship. Moreover, the studies conducted by Kunyoria, (2018); Malonza, (2014) focusing on Mumias Sugar Company Limited, Kenya, and South Nyanza Sugar Company, Awendo Kenya, respectively, used relatively small case studies. Consequently, the outcomes might not be readily applicable to other contexts, limiting the generalizability of their findings. Moreover, Kunyoria, (2018) study result (β=0.672, p = 0.037) indicates a significant relationship as well, but the proximity of the p-value to the significance threshold suggests a slightly weaker level of confidence.

Furthermore, none of the reviewed studies incorporated all the following essential lean manufacturing practices to constitute a cohort metric to measure LM value stream mapping, continuous improvement, Just-in-Time, and total productive maintenance proposed by Rocha-Lona *et al*., (2013) which additionally will affect operational performance and determine its moderation effect on the association among product design and operational performance. This oversight could have influenced the impact of lean manufacturing on operational performance in those studies. Finally, only two of the reviewed studies Malonza (2014) and Kunyoria (2018) did take Sugar Subsector as a case study hence forming a basis for this study in this subsector.

2.2.3 Lean Manufacturing, Product Design and Operational Performance

With the advent of a dynamic and rigid business landscape, embracing lean manufacturing practices becomes essential in safeguarding effective operational performance (Malonza, 2014; Nawanir, 2016; Seng *et al*., 2021). Lean manufacturing induces operational performance as established by Hernandez-Matias *et al*. (2019; Malonza (2014); Nawanir (2016); Seng *et al*. (2021). Wastes in the production line are unavoidable (Lazai *et al*., 2020; Shi *et al*., 2019; Zahraee *et al*., 2020) and come in various states (Goshime *et al*., 2019). As a result, for the advantage of the company's stakeholders, production continuity must be maintained by improving service delivery, offering high-quality products, reducing production time, maintaining production continuity, and improving the transformation process by increasing the number of sales, lowering production cost per unit, and increasing market share. In reference to the above reviewed literature, product design, lean manufacturing, and operational performance indicators essentially exist jointly, even though there is lack of scientific investigation conducted to determine the link between the three essentially existing indicators as a cohort. This informed the current study as it empirically established the interplay between product design and operational performance when lean manufacturing, which eliminates waste in the production line, was introduced into the metric as a moderator variable

Moderating effects are stirred by variables whose discrepancy affects the quality of association among the predictor and outcome variables (Baron & Kenny, 1986; Lai, 2013). The results associated with the moderating effects are termed “moderator variables” or “moderators”(Fassott *et al*., 2016). The moderation effect stipulates a way to analyze if the intervention leads to uniform outcomes among the groups (Farooq & Vij, 2017). This study was guided by the moderating variable. This is due to the moderating variable's influence on the trajectory of an originator's effect on a result (Aguinis *et al*., 2017). The choice of a moderating variable should be informed on the basis of strong theoretical support (Farooq & Vij, 2017), hence this informed the choice of RBV and transaction cost theory.

Gilal *et al*. (2018) in their study linking product design to consumer behavior adopted consumption experience as the moderator and did not address lean manufacturing as a moderator. They postulated a weak association of the moderator on the interplay between product design and consumer behavior ($\beta=0.434$, $p=0.006$). Lee and Johnson (2017) carried out a study on the effect of new product design and innovation on South Korean consumers’ willingness to buy (WTB). They adopted individual innovativeness and individual product knowledge as independent moderators. Innovation in technology had a noteworthy moderating effect with respect to the association between new product design and willingness to buy ($F (1, 59) = 4.27$, $p<0.05$) postulated that the degree of technical innovation determines how to form design is guided on WTB radically new product or low on n incrementally new product. Based on this, lean manufacturing may be used as a solution to these inconsistent outcomes and the poor correlations between product design and operational performance.

Within the purview of the literature review, a discernible void exists in terms of targeted scholarly investigations delving into the moderating influence of lean manufacturing on the interplay between product design and operational performance. Though there are studies done that give a clue of a possible relationship among product design, LM and operational performance having determined lean manufacturing as an architecture of product design and operational performance. For instance, a study by Kariuki (2016) to determine the production system design and operational performance of steel manufacturers in Kenya established result of ($F = 2.575$,$\rho=0.004$) indicating a weaker association between production system design and operational performance the weak association may be because the study ignored to conduct the moderation effect. Besides that, Roble & Wanjira (2021) while writing on effects of product design on performance of commercial banks in Garissa County, Kenya did not adopt a moderator and the study result (β=0.729 and ρ= 0.001) established a weak relationship. Ahmad *et al*. (2018) focused on the impact of product design and process design on new product performance in the manufacturing industry and utilized a nationwide sample comprising 100 Malaysian companies, the study adopted new product and new process designs as independent variables with r= 0.092 and r= 0.570 results respectively. The study revealed a proportional association (r=0.570) between new product process design and product performance. However, no substantial correlation was registered between new product design and product performance. This may have resulted because the study did not adopt a moderator.

Prior studies have also revealed the effect of product design on operational performance. However, failed to view product design, lean manufacturing, and operational manufacturing as a unit cohort to form metrics to measure LM. They relatively failed to address lean manufacturing practices which are the highest classified operations management sub-branch affecting operational performance. Subsequently, if product design and lean manufacturing are adopted as a cohort to establish operations management activities', their influence on operational performance is not known. Hence, the current study was part of the dynamic scholarly write-ups by modeling lean manufacturing's impact on the association between product design and operational performance among Sugar Firms in Kenya by focusing on the entire product lines right from the input stage to the transformation stage and output stage.

The reviewed studies above ignored adopting leaning manufacturing as a moderator to establish its interplay between product design and operational performance. Hence, they were unable to determine how and which LM practices affected the firm's operational performance under study. Besides that, the reviewed studies were based on small case studies and hence the findings may not be generalized. Similarly, an attempt by prior scholars' operational performance metrics to establish the influence of lean manufacturing applied weak measures of operational performance with a focus on the elimination of waste at the input level and output level rather than the whole manufacturing system which is key in any manufacturing organization's transformation process.

Nevertheless, with all the scholarly trials investigating lean manufacturing's influence on operational performance, there is still insufficient information. This calls for a robust exploration of the LM practices to establish waste and its elimination/mitigation strategy which directly affects operational performance. This study also deployed the four main lean manufacturing practices proposed by Rocha-Lona *et al*. (2013) which include; value stream mapping, continuous improvement, Just-in-Time, and total productive maintenance which additionally affected operational performance and establish its moderation effect on the interplay between product design and operational performance.

CHAPTER THREE

RESEARCH METHODOLOGY

In this chapter, various elements of the research methodology are elucidated, detailing the approaches employed to tackle the research issue and accomplish the study's objectives. The components covered encompass research design, study location, study population, sampling framework, data type, procedures for data collection, reliability and validity assessments, as well as the analysis and presentation of findings. Subsequent subsections delve into the discussion of each of these aspects.

3.1 Research Design

Sreejesh *et al*. (2014) defined research design as a guide aimed at conducting research by defining the key procedures for data collection, measurement, and data analysis in order to address the research problem. This study was guided by a correlational research design. Creswell (2015) postulated that correlational research design as the use of statistical tests to establish the pattern or tendency between two (or more) variables or sets of data to vary consistently. Correlational research is focused on determining interactions amongst two or more indicators in the same case study or between the same variables in two case studies (Leedy & Ormrod, 2010). Cheng (2016) argued that correlational research design describes the relationship between two or more variables.

3.1.1 Research Philosophy

Research philosophy is a cohort of beliefs and assumptions on knowledge development (Saunders *et al*., 2016). Saunders *et al*., (2007) divided research philosophies into three categories; interpretivism, realism, and positivism. Positivism research philosophy expresses that reality is stable. Positivism applies a hypothetico-deductive method to determine priori hypotheses quantitatively and purposeful associations potentially acquire between explanatory and causal factors (Jacobs & Chase, 2008). Positivism relies on the importance of what is under review as a whole and strictly focuses on pure data and facts without bias of human interference (Scotland, 2012). Positivism states that individuals can be able to identify facts from their beliefs and values objectively (Bahari, 2010). The foundation of positivism is a highly structured methodology that allows for generalization, quantifiable observations, and statistical evaluation of the results (Ryan, 2018).

Mason (2018) defined interpretivism as a research paradigm that allows the researcher to integrate with human interest so as to interpret and understand the meaning of a particular study. Creswell and Creswell, (2017), also defined interpretivism as qualitative research that has a philosophical partner. Pulla and Carter, (2018) interpretivism is a research pattern associated with qualitative research. Interpretivism logically analyses sociological interpretations by directly observing people in a natural setup so as to understand and interpret how they establish and uphold their social worlds (Neuman, 2014).

The positivism research philosophy served as the study's guiding philosophy. This is because the positivism research philosophy is of the understanding that factual knowledge is attained via observation (the senses), as well as measurement is trustworthy (Saunders *et al*., 2009). Verhaegh (2020) argued that positivist model proclaims that real phenomena can be pragmatic empirically and substantiated by logical analysis. Positivism research philosophy expresses that reality is stable. Positivism applies hypothetico-deductive method to determine priori hypotheses quantitatively and functional associations may be consequential among causal and explanatory factors (independent variables) and outcomes (dependent variables) (Jacobs & Chase, 2008).

3.2 Study Area

The research was conducted within the context of Sugar Milling Companies in Kenya, encompassing: Muhoroni Sugar Company, Chemelil Sugar Company, Mumias Sugar Company, Nzoia Sugar Company, Sony Sugar Company, Miwani Sugar Company, Ramisi Sugar, West Kenya Sugar Company, Soin Sugar Company, Kibos Sugar & Allied Industries Limited, Butali Sugar Mill limited, Transmara Sugar Company, Sukari Sugar Company, Kwale International Sugar Company, Ole Pito Sugar Company, and Busia Sugar Company. The study was based on western Kenya Sugar Companies. Western Kenya Sugar Firms was selected because according to Kenya Association of Manufacturers, (2020) it has 75% of Sugar Firms.

3.3 Study Population

The target population of this study was based on a sample frame of 16 Sugar Companies in Kenya, targeting respective assistant managers and managers as established by the Kenya Association of Manufacturers, (2020) as indicated in appendix IV. According to the Kenya Association of Manufacturers, (2020) there are sixteen sugar producing companies in Kenya which include Muhoroni Sugar Company, Chemelil Sugar Company, Mumias Sugar Company, Nzoia Sugar Company, Sony Sugar Company, Miwani Sugar Company, Ramisi Sugar, West Kenya Sugar Company, Soin Sugar Company, Kibos Sugar & Allied Industries

Limited, Butali Sugar Mill limited, Transmara Sugar Company, Sukari Sugar Company, Kwale International Sugar Company, Ole Pito Sugar Company and Busia Sugar Company.

In the sugar sub-sector in Kenya, a specific group of firms with commonality in their operationalization was identified. The study adopted inclusion (should be milling currently) and execution criteria (entailed closed firms, those under receivership). 12 milling sugar firms were used as units of observation for this study, excluding three for being under receivership and one for being closed as indicated in appendix IV. This is in agreement with Stanley, (2007) who postulated that inclusion and exclusion criteria establish the units that may be involved in or omitted from the study sample.

3.4 Sample Size

Saunders *et al*., (2007) postulated that sample size involves selecting individuals from the population, ensuring a sufficient and accurate representation of the entire population. The sample size comprised 164 respondents, consisting of 82 departmental managers and 82 assistant managers, serving as units of analysis, as indicated in Appendix V of the Sugar Firms in Kenya. The choice for managers and assistant managers was based on their direct engagement with systems and active participation in implementing functional practices make them well-suited sources for capturing accurate and comprehensive data, aligning with the study's objective of exploring the association between manufacturing activities and operational performance. The study used a census survey as a guide for data collection from 164 sugar firms' employees in Kenya. A census survey was suitable for this study because it is applied when all the units of observation in a study are considered and they are of a small sample size (Kothari, 2004). Similarly, Idoko (2011) census survey stipulates that all the members of the population are considered in a study. Australian Bureau of Statistics (2015) census survey is appropriate when gathering data from all units in the population and most suitable for small units of observations.

3.5 Data Collection Methods

3.5.1 Data Types and Data Sources

This study used a combination of primary and secondary data based focusing on indicators related to product design, lean manufacturing and operational performance. Primary data was collected using questionnaires from employees of Sugar firms in Western Kenya (departmental managers and assistant managers). Secondary data was harvested from the published and unpublished thesis, textbooks, periodic reports, journals, online publications, the internet, as well as library resources to enhance a robust literature review to yield enhanced results.

3.5.2 Data Collection Procedures

The researcher was first issued with a research letter of introduction from Maseno University's School of Post Graduate Studies which the researcher used for sourcing endorsement from Ethics Review Committee of Maseno University and National Council for Science, Technology and Innovation (NACOSTI) to gather data from Sugar Firms in Kenya.

A pilot study was conducted using a census survey involving 14 participants from Transmara Sugar Company in Narok County to confirm the reliability of the data collection tool. Transmara Sugar Company was selected for the pilot study as guided by Doody and Doody (2015) who postulated that to effectively evaluate proposed data collection and analysis techniques and identify potential issues, it is prudent for researchers to conduct a pilot study of the research on a small group of participants who share similarities with those who will be recruited for the full-scale study. Fourteen pilot study participants are decisive as postulated by Saunders *et al*. (2007) who confirmed that ten participants are the least conceivable number of pre-testing a data collection tool. After acquiring the necessary approvals, material for data collection was constituted. Subsequently, a team consisting of one research assistant as the lead supervisor and six additional research assistants was recruited. The researcher also sorted for authorization from the management of the Sugar Firms in Kenya. After the authorization, the units of observation were issued with research questionnaires and requested to fill in. The questionnaires were self-administered by issuing and collecting them shortly after their completion to cure the possibility of duplicate responses.

The rates of response returns of employees from various Sugar Firms in Kenya are established in Table 3.1. Among the companies surveyed, Chemelil Sugar Company had a response return rate of 80.0%, Nzoia Sugar Company attained 81.8% response return rate, Sony Sugar Company had 77.8% response return rate, Butali Sugar Mills Limited had 83.3% response return rate, with Sukari Sugar Company having a response return rate of 94.4%, Kibos Sugar & Allied Industries Limited having a response return rate of 83.3%, West Kenya Sugar Company having a response return rate of 87.5%, Ole Pito Sugar Company having a response return rate of 81.3% and Busia Sugar Company exhibited a rate of response return of 77.8%. The grand total rate of response was recorded at 82.9%. which conforms to (Ary *et al.*, 1996; Fowler Jr, 1993) who postulated that a minimum response return of 75% is significant.

Table 3. 1: Response Return Rate

Sugar Firm	Proposed Sample	Response return rate (%)
Chemelil Sugar Company	20	16(80.0)
Nzoia Sugar Company	22	18(81.8)
Sony Sugar Company	18	14(77.8)
Butali Sugar Mills Limited	18	15(83.3)
Sukari Sugar Company	18	17(94.4)
Kibos Sugar & Allied Industries Limited	18	15(83.3)
West Kenya Sugar Company	16	14(87.5)
Ole Pito Sugar Company	16	13(81.3)
Busia Sugar Company	18	14(77.8)
Grand total	**164**	136(82.9)

Source: Survey data, (2023)

3.5.3 Data Collection Instruments

Questionnaires were employed as data collection instruments from all managers and assistant managers of 9 Sugar Companies in Kenya. This research adopted closed ended questions, which constrained responses to a predefined number of responses that produced accurate results to advance the empirical investigation. In crafting the research questionnaire, a five-point Likert scale was applied to gauge the degree of sentiment among respondents regarding the correlation between product design, lean manufacturing and operational performance among Kenyan Sugar Firms. In which a rating of one indicates strong disagreement on a phenomenon or proclamation and a rating of five stands for a strong agreement in that sequence (Patton, 2002).

3.5.4 Validity Tests of the Research Instrument

Bashir *et al*., (2008), postulated that validity is the degree to which a test measures what it is intended to measure, the degree to which it is truthful, accurate, authentic, genuine, or sound, and the degree to which the measurement tools are reliable and effectively assessing what they are supposed to measure. Assessing the research instruments was based on four fundamental ways of validity include; content validity, construct validity, face validity, and criterion validity (Zikmund *et al*., 2010).

Content validity was realized through reviewing the instrument's content and format and determining whether or not it will be necessary as advised by experts as recommended by (Bolliger & Inan, 2012). Through the use of the eight experts specialized in Operations Management and Logistics Management from Maseno University's School of Business and Economics content validity was ensured. This is in agreement with DeVon *et al*., (2007) who postulated that seven or more experts are ideal in testing for content validity. The experts were given questionnaires to evaluate and score each indication in connection to the study objectives, using a scale of 1 to 4, wherein 1 indicated lack of relevance, 2 represented partial relevance, 3 denoted moderate relevance, and 4 signified high significance. Contact experts evaluated the significance of the content incorporated into the data gathering tool. Experts' endorsements were adopted to make the necessary improvements to the final questionnaire. Face validity was achieved through subsequent input from the research supervisors and expert judgment (Blumberg *et al*., 2014). The researcher adopted recommendations from the supervisors and the eight experts specialized in Operations Management and Supply Chain Management from the Maseno University's School of Business and Economics to ensure face validity is attained.

The experts asserted that to maintain confidentiality, it was unnecessary to include demographic questions that requested information about their firm's identity and role. They raised concerns about potential bias, and upon discussing the matter with my supervisor, we decided to exclude these questions from the final questionnaire.

Both translation and criterion-related validity methods were used to establish construct validity. (Trochin, 2006). The research instrument's operationalization is evaluated for its ability to faithfully reflect the intended relevance of the original notion, through translation validity. Therefore, translation validity sought to evaluate the extent to which conceptions were dependably operationalized among the research variables: product design, lean manufacturing and operational performance (Drost, 2011). Criterion validity was attained through correlation analysis as shown in Table 3.2, with criterion validity measured by assessing the relationship between a measure (e.g., "product design") and an established criterion or gold standard measure (e.g., "lean manufacturing" or "operational performance"). The collected data were analyzed for correlations. Where r = 0.7 – 0.89 was considered as very highly, r = 0.5 – 0.69, moderate correlation, r = 0.26 – 0.49, low correlation and r = 0 – 0.25, very low as postulated by (Munro, 2005). Low correlations indicated that variables are weak relationships among the study variables or they are discriminating against each other. Dissimilar constructs are characterized by low intercorrelations suggesting discriminant (Drost, 2011). Because of its multi-item form and the perception that it effectively covers the underlying theoretical characteristics, the measurement scale favored in the literature was employed in this study to operationalize product design (Heizer *et al*., 2017; Sayar & Er, 2019).

Table 3. 2: Criterion Validity Assessment of "Product Design," "Lean Manufacturing," and "Operational Performance"

Correlations

		Product design	Lean Manufacturing	Operational Performance
Product design	Pearson Correlation	1	.627*	.722**
	Sig. (2-tailed)		.016	.004
	N	14	14	14
Lean Manufacturing	Pearson Correlation	.627*	1	.616*
	Sig. (2-tailed)	.016		.019
	N	14	14	14
Operational Performance	Pearson Correlation	.722**	.616*	1
	Sig. (2-tailed)	.004	.019	
	N	14	14	14

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Source: Survey data, (2023)

Criterion validity was employed to evaluate the level of accuracy with which the three primary parameters "product design," "lean manufacturing," and "operational performance" measured the intended constructs. Criterion validity analysis allows for a comparison between the scores obtained from the new measures ("product design") and the established criterion measures ("lean manufacturing" and "operational performance") that assess the same constructs.

As indicated in Table 3.2, correlation analysis between "product design" and "lean manufacturing" revealed a significant positive concordance , with a correlation coefficient of 0.627 ($p < 0.05$). This finding indicates a substantial connection between "product design" is related to "lean manufacturing," providing evidence of criterion validity. The statistically significant correlation suggests that the "product design" variable accurately measures similar aspects to the established "lean manufacturing" measure. The correlation analysis between "product design" and "operational performance" demonstrated a significant positive concordance, with a correlation coefficient of 0.722 ($p < 0.01$). This robust correlation further supports the criterion validity of "product design." The results imply that "product design" aligns strongly with "operational performance," indicating that it effectively measures relevant aspects of operational performance. The correlation analysis between the established measures of "lean manufacturing" and "operational performance" yielded a significant positive correlation of 0.616 ($p < 0.05$). This significant relationship supports the criterion validity of "lean manufacturing," indicating that it accurately measures aspects that are related to "operational performance."

In summary, the correlation analysis provided compelling evidence of criterion validity for all three variables: "product design," "lean manufacturing," and "operational performance." The significant positive correlations between each variable and the established measures ("lean manufacturing" or "operational performance") indicate that these variables effectively measure related aspects of the same construct. These findings lend support to the accuracy and validity of the "product design," "lean manufacturing," and "operational performance" measures, reinforcing their suitability for assessing specific constructs in the context of this study.

3.5.5 Reliability Test for Data Collection Instrument

The primary aim of conducting a pilot study was to pretest the data collecting tools, thereby reducing measurement errors and advance the reliability of the construct analyzing and addressing issues with the question's structure and design (Dillman, 2000). A pilot study was carried out at Transmara Sugar Company, a privately owned sugar firm based in Narok County, to confirm the reliability of the data collection instrument to be adopted for this study. Transmara Sugar Company was selected because it is in the same industry in relation to the case study. The pilot study involved fourteen participants constituting managers and assistant managers of seven departments in Transmara Sugar Company. This sample is ultimate as recommended by Saunders *et al*., (2007) who attested that at least ten participants of pretesting are sufficient. An introduction letter, research permit, and questionnaire copies were issued to Transmara Sugar Company before conducting the pilot study of the selected participants. Transmara Sugar Company as a unit of observation was not considered in the final study as it was utilized in the pilot.

Reliability is the magnitude at which findings are uniform gradually and accuracy with which they reflect the broader population being studied holds that study outcomes can be replicated in a comparable research approach, hence, the research instrument is considered to be reliable (Joppe, 2000). Pilot data was coded and then the researcher conducted an initial analysis using Cronbach‘s alpha to examine the questionnaire’s reliability. In tests and scales of research instruments, Cronbach's alpha is a statistical tool used to measure the suitability of their purpose (Taber, 2018). As recommended by Peterson, (994) cronbach’s alpha values span from 0 to 1 with segment of 0.8 to 1.00 demonstrating significant reliability, values ranging from 0.70 to 0.80 specifying acceptable reliability whereas values below 0.70 are less reliable and unacceptable. The reliability analysis results help to establish if the questionnaire should be reviewed or not. Table 3.3 presents the results obtained for the instrument's reliability assessment.

Table 3. 3: Reliability test for the Study Instruments

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Product Design	5.5911	1.794	.755	.575	.754
Lean Manufacturing	6.0464	2.274	.670	.449	.839
Operational Performance	5.7946	1.802	.747	.566	.763

Source: Survey data, (2023)

As established in Table 3.3, the reliability results are displayed in the "Alpha if Item Deleted," column, illustrating the effects of omitting individual items out of the scale. As observed, it becomes evident that no values within this column exceeded the ultimate alpha threshold (.849). The established good internal consistency of the scale indicated adequacy of the reliability for the data collection instruments. The overall reliability test results demonstrate that Cronbach's alpha value surpassed the accepted margin of 0.70, indicating satisfactory instrument reliability.

Table 3. 4: Summary Cronbach's Alpha for Reliability Test

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.849	.851	30

Source: Survey data, (2023)

The collective outcome of reliability test demonstrated that Cronbach's alpha value surpassed the accepted margin of 0.70, indicating satisfactory instrument reliability. As a result, the instruments were deemed reliable for data analysis.

3.6 Data Analysis Techniques

In the context of this research, multiple linear regression analysis was adopted to investigating the connection between the explanatory factors; product design represents the independent variable, the moderator variable (lean manufacturing) and operational performance represents the dependent variable. The research utilized combination of descriptive and inferential statistics. Descriptive statistics entail the computation of frequency distribution, mean, median, and standard deviation. The research used inferential statistics through regression analysis to determine the type and strength of correlations among the study variables under consideration. Data were displayed using figures and tables.

3.6.1 Model Specification

This study modified and adopted a multiple linear regression model reviewed by Fairchild and MacKinnon (2009) to establish the simultaneous relationship among product design, lean manufacturing, and operational performance as illustrated below:

Objective 1

$Y_{ij}= \beta 0+\beta_1 X_{ij} +\varepsilon_i$………………………………..………………………………………… (3.1)

Y_j represents operational performance, measured using a 5-point Likert scale.

X_j represents product design

j ranges from 1 to 136

$Y_{ij}=\beta 0+\beta_1(EM)_{ij}+\beta 2(QFD)_{ij}+\beta 3(SCM)_{ij}+\beta 4(DT)_{ij}$ $+\varepsilon_i$……………………………………..(3.2)

Where i =1 or 2 (Y1= operational performance and Y2 is mean scores) and E-manufacturing (EM), Quality function deployment (QFD), Supply chain management (SCM), Digital Technologies (DT)

$Y_{ij}= \beta_0+\beta_1 X_{ij} +\varepsilon_o$………………..……………………………………………………… (3.3)

i=1, 2, 3, 4, 5 and Y_1 is Speed of production, Y_2 is Product quality, Y_3 is Production flexibility, Y_4 is Product dependability, Y_5 is Production cost

β_0= Represents the y-intercept within the equation.

β_1 = Magnitude of the causal impact of X, indicated by the coefficient of product design.

εi = Represents the error term.

X_i is the product design sub-indicators E-manufacturing (EM), Quality function deployment (QFD), Supply chain management (SCM), Digital Technologies (DT)

j=1,2,3,…136

Objective 2

$Y=\beta_0+\beta_1 Z_{ij}+\varepsilon_0$…………………………………………………………………….. (3.4)

Y denotes operational performance, and Z signifies lean manufacturing practices.

$Y_{ij}= \beta_0+\beta_1 Z_{ij} +\varepsilon_i$……………………………………………………………………… (3.5)

Y_i= Operational performance

i =1, 2, 3, 4, 5 and Y_1= Speed of production, Y_2 is Product quality, Y_3 is Production flexibility, Y_4 is Product dependability, Y_5 is Production cost

Z_j = Lean Manufacturing practices

β_2 = Magnitude of the causal impact of Z, as indicated by the coefficient of lean manufacturing practices.

ε_i = Refers to the residual within the equation.

j ranges from 1 to 136

Objective 3

$Y_j= \beta_0 +\beta_1 X_{ij}+\beta_2 Z_{ij}+\beta_3 X_{ij} Zi_j+e_i$ …… ………………………………………………… 3.6

In this research, the alteration consisted of substituting the variables in the Fairchild & MacKinnon, (2009) model's variables with those that were established.

Where;

Y= Operational performance

Y_i= the dependent variable analyzed using product quality, production flexibility, product dependability and production cost sub-indicators.

X and Z = product design Process and lean manufacturing practices respectively

X_{1i}= the independent variable (product design) measured by e-manufacturing, quality function deployment, supply chain management and digital technologies sub-indicators.

XZ = Interaction Term (product design * lean manufacturing)

β_0 = Represents the y-intercept within the equation.

β_1 = Size of X's causal effect, (Product Design Coefficient)

β_2 = Size of Z's (the coefficient of lean manufacturing practices) causal effect

β_3 = The extent of the causal impact of the interaction term, XZ, (coefficient of the interaction term).

$\beta_1\beta_2\beta_3$ = The coefficients of product design –X_{1i}, lean manufacturing practices -Z_2 as well as the moderator variable, denoted as Z_iX_i.

ε_i = Error term.

j ranges from 1 to 136

3.6.2 Model Assumptions

When incorporating regression analysis in a research study, the data must meet some assumptions. Regression analysis was thus not be used unless the investigation was based on the following hypotheses;

i. variable category (like, the indicator ought to be ratio or normal scale)
ii. The mean of the error term is zero:- E (εt) = 0
iii. The variance of the error term is constant E ($\varepsilon_t{}^2 = \sigma^2$)
iv. The error term is typically distributed and it has a zero constant variance and mean:-

   $\varepsilon_t \sim N(0, \sigma^2)$

v. The error term is not influenced by the explanatory variables.
vi. The error terms across various observations are uncorrelated. i.e. Cov

   $(\varepsilon_t \varepsilon_{t-1}) = E(\varepsilon_t \varepsilon_{t-1}) = 0; t \neq t-1$

vii. Epsilon represents the actual random indicator that can either be negative, zero, or positive values.
viii. The study variables analyzed are error-free.
ix. Study association is appropriately quantified.
x. The adopted model is multicollinearity free.

The prerequisite of detecting any deviations based on outlined linear assumptions is articulated by (Fairchild & MacKinnon, 2009). The assumptions were tested systematically.

3.6.3 Types of Variables

This study adopted variables that are scalar as proposed by Field, (2000) who urged that with only exception (type of ownership), all variables are scalar or measured in intervals and hence perceived to be in contrast to the variable metric with the dependent variable is explored.

3.7 Diagnostic Tests for Regression Analysis

3.7.1 Test for Normality

One of the fundamental assumptions of the classical linear regression model is normality. Normality assumption is key in establishing unbiasedness of the standard errors and ensures that residuals of the model are normally distributed (Schmidt & Finan, 2018). This assumption is realized when data from stand-alone indicators relate to normal distribution indicators. The research study was tested for normality by adopting a normal probability plot (P-P plot) to establish if the residuals of the model followed a normal distribution or not by use of histograms as established in figure 3.1.

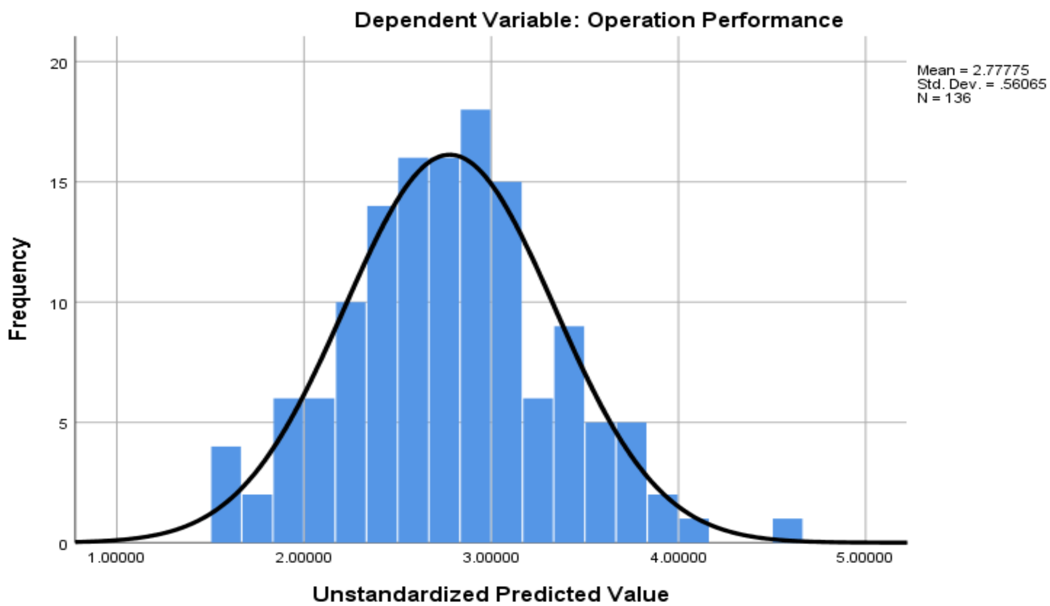


Figure 3. 1: Histogram of Regression Standardized Residuals for Operational Performance with Normal Plot
Source: Survey data (2023)

Analysis of a histogram on standardized residuals of the regression and a normal probability plot (P-P plot) of regression standardized residuals is depicted in Figure 3.1, were used in this study to assess the normality of the data. Operational performance was examined using a normal probability plot (P-P plot) and a histogram analysis of regression standardized residuals. The findings were presented in sections of linearity and homoscedasticity diagnostics. Both analyses indicated a normal distribution for operational performance, signifying that the data met the assumption of normality.

3.7.2 Test for Homoscedasticity

This assumption ensures that the error terms variance is identical transversely in all the values of the independent variable. Heteroscedasticity is noted when the variance of errors varies with the independent variable's values. There is a negligible impact on statistical tests the slight heteroscedasticity has; nevertheless, when the establishment of heteroscedasticity can result in eminent impairment of the findings and reduce the analysis, therefore, enhancing probability of a Type I error (Berry *et al*., 1985; Tabachnick & Fidell, 1996). Homoscedasticity is evaluated visually by administering a plot displaying the connection between the standardized residuals (errors) and the regression standardized predicted values. This was done for the measure of the outcome variable (operational performance) and the aggregate of the predictor indicators (e-manufacturing, quality function deployment, supply chain management, and digital technologies) with the aid of a normal probability plot (P-P plot). The outcome variable must display consistent amounts of deviation across different predictor factors in order to be homoscedastic. Failure to meet this assumption can compromise the accuracy of the r coefficient. Mistakenly assuming homoscedasticity when it is actually heteroscedastic can result in an overestimation using the Pearson coefficient, which gauges the goodness of fit. Figure 3.2 illustrates this concept.

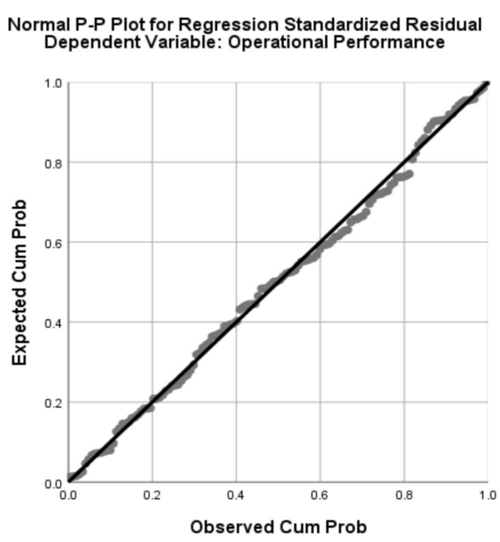


Figure 3. 2: Normal P-P Plot for Regression Standardized Residuals for Dependent Variable

Source: Survey data (2023)

To assess the fulfillment of the assumptions concerning random error and homoscedasticity, a graph illustrating the standardized disparities between actual observations and the values estimated by the regression model (ZRESID) was plotted against the standardized predicted values of the dependent variable (ZPRED), as illustrated in figure 3.2.

3.7.3 Test for Linearity

The dependent variable, y, according to this assumption, may be expressed as a linear combination based on certain independent variables along with an error term. (Berry & Feldman, 1985; Cohen, 1983; Pedhazur, 1997) proposed three main approaches for identifying non-linearity. The first approach involves utilizing theory or existing research to guide the current analysis. This method is not fully dependable, though, as earlier researchers might have overlooked the existence of non-linear correlations. However, due to the potential neglect of considering non-linear connections by earlier researchers, the efficacy of this method might be somewhat compromised.

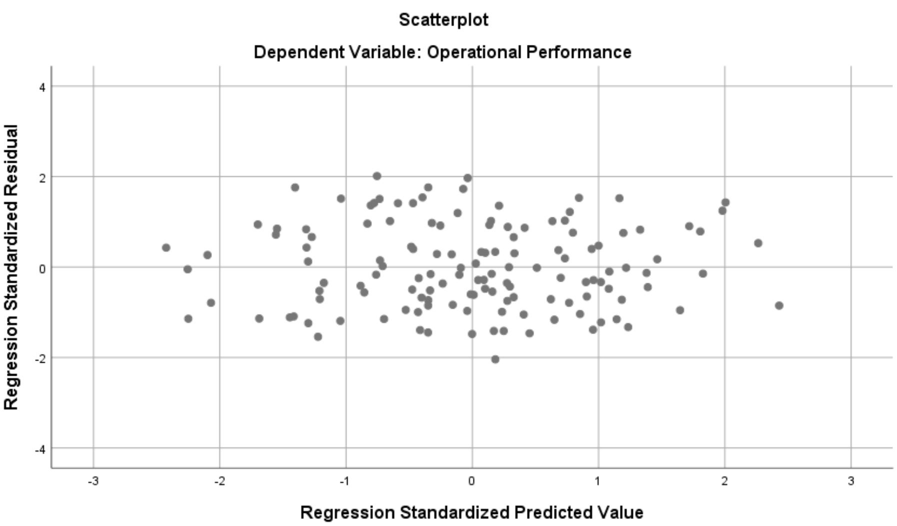


Figure 3. 3: Scatter plot of ZRESID against ZPRED for operational performance

Source: Survey data (2023)

As portrayed in Figure 3.3 the points in the scatter plot appear to be distributed in a random and uniform manner. Additionally, the shows a rectangular shape, which satisfies the requirements for linearity and homoscedasticity. Furthermore, the regression-standardized residuals' normal scatter P-P plot demonstrates a rectangular shape, fulfilling the necessary conditions for linearity and homoscedasticity. Additionally, as postulated by Field, (2000), there is no presence of a curvilinear pattern, which further reinforces the assumption of linearity.

3.7.3 Testing for Multicollinearity

Multicollinearity is attained if the independent variables are established to be highly correlated and hence declare them redundant (Yoo *et al*., 2014). Investigation of the correlation matrix of the independent variables was computed using variance inflation factor (VIF) and correlation matrix.

Table 3. 5: Collinearity Statistics

Coefficients[a]

Model		Collinearity Statistics	
		Tolerance	VIF
1	Independent variable		
	Product Design	.653	1.531
	Lean Manufacturing	.762	1.312

a. Dependent Variable: Operational Performance

Source: Field pre-survey (2023)

VIF signifies the extent of multicollinearity in a regression analysis (Ernest, 2012). When a tolerance value is less than 0.10 or the values of the VIF are larger than 10, multicollinearity is realized; the severity of the issue is realized when the values of the VIF are advanced. (Field, 2000). The outcomes of the multicollinearity statistics are shown in Table 3.5. The table reveals that there were no substantial multicollinearity issues in the data, with all tolerance statistics for this analysis exceeding 0.10 and all VIF values were significantly lower 10 (Perreault, 1991 & Field, 2000; Mason). Consequently, the analysis led to the conclusion that there was no significant multicollinearity present in the data.

3.8 Research Ethics

Since data collection involved human subjects, it was the researcher's responsibility to fully ensure respondents' privacy is attained throughout the research period. The researcher sought endorsement starting with National Commission for Science, Technology, and Innovation (NACOSTI), Maseno University's Ethics Review Committee of, and then from the management of the sugar companies under study. As this entailed an explanation of the objective of the study and its impact on the industry under review.

After obtaining authorization, the targeted respondents were assured that their involvement in the study was entirely self-regulated and without coercion. Respondents who wished to pull out did not face any negative consequences for declining to participate or withdrawing their involvement.

To ensure ethical conduct during data collection, the researcher undertook key activities to prioritize participants' rights and well-being. This was achieved through obtaining informed consent, protecting confidentiality and anonymity, adhering to data protection regulations, and responsible data analysis and reporting. The researcher obtained informed consent from all participants. This involved providing them with comprehensive details about the study, which entailed its objectives, methodologies, possible risks and advantages, as well as their entitlement to pull out their participation at any point. The researcher guaranteed the privacy and confidentiality of all participants. This involved using codes instead of names to protect the participant's identities, ensuring that their personal information is kept private, and storing all data in a secure location. The researcher adhered to relevant data protection regulations and guidelines to ensure the secure storage and handling of collected data. The researcher, further, took measures to prevent any physical, psychological, or social harm to the participants. This involved conducting a risk assessment before the study begins (during the pilot study stage) to identify potential risks and take measures to mitigate them. Besides that, the researcher conducted data analysis and reporting in a thorough, unbiased, and transparent manner by clearly distinguishing between empirical findings and subjective interpretations, avoiding any manipulation or misrepresentation of data. The researcher communicated the study's results to the participants and all the stakeholders involved in the study. This involved presenting the findings in an easily understandable format and ensuring that the participants understand the implications within the research.

CHAPTER FOUR

RESULTS AND DISCUSSION

The study's outcomes, inferences, and discussions aligned with research's general objective and specific study objectives are addressed in this chapter. The measuring of operational performance is the first step in this section's presentation of the results, which is followed by the testing of the hypotheses. All tests of significance were conducted at a significance level (α) of 0.05. The conventional test threshold employed to support the assertion of a statistically noteworthy effect is 0.05. In common usage, the terminology "statistically significant" is associated with $p < 0.05$ (Moore, 2009).

4.1 Measure of Operational Performance

Prior to addressing the study objectives, evaluating the measurement for the dependent variable, operational performance was crucial. Participants were asked to express their perspectives regarding how respective sugar firms perceived operational performance. The questionnaire encompassed questions considered vital for assessing operational performance, specifically focusing on speed of production, product quality, production flexibility, product dependability, and production cost. Responses were assessed using a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). An average score greater than 3.0 indicated agreement, while a mean below 3.0 suggested disagreement. A neutral point of 3.0 indicated respondents' uncertainty about their feedback. The outcomes were presented using descriptive statistics, encompassing frequency counts, percentages, means, and standard deviations. This approach was employed to present the findings and highlight the variation in responses.

Table 4. 1: Operational Performance

Operational performance	SD f (%)	D f (%)	N f (%)	A f (%)	SA f (%)	MEAN	SD
My firm produces goods at a price that allows them to be valued fairly in the market			19(14.0)	55(40.4)	62(45.6)	4.32	.707
My firm utilizes technology to relevant technology to lower the cost of production		1(.7)	21(15.4)	65(47.8)	49(36.0)	4.19	.715
My firm has the capacity to adjust its operations to deal with unforeseen occurrences	4(2.9)		11(11.0)	68(50)	49(36)	4.16	.845
My firm quickly adapts to changes particularly consumer wants and expectations			25(18.4)	60(44.1)	51(37.5)	4.19	.725
My firm´s product quality has promoted consumer loyalty			22(16.2)	67(49.3)	47(34.6)	4.18	.691
My firm produces goods based on the market dynamics			24(17.6)	69(50.7)	43(31.6)	4.14	.690
My company delivers goods right on time		1(.7)	23(16.9)	53(39.0)	59(43.4)	4.25	.758
My firm takes the shortest time to respond to commended production changes			24(17.6)	62(45.6)	50(36.8)	4.19	.715
My firm responds to customer needs and orders as they arise			22(16.2)	64(47.1)	50(36.8)	4.21	.700
My firm takes a minimum set time to produce goods per unit			26(19.1)	82(60.3)	28(20.6)	4.01	.632
Overall mean						4.18	0.717

Source: Survey data (2023)

Table 4.1 presents the findings, cost of production was evaluated by two statements. In the first statement ‘‘my firm produces goods at a price that allows them to be valued fairly in the market’’, majority of respondents rated the statement positively 45.6% (strongly agree) the mean score stands at 4.32, validating the findings. Additionally, the standard deviation (SD =

0.707) suggests some variations in the responses from the participants. In the second statement, ‘‘my firm utilizes technology to relevant technology to lower the cost of production’’, majority of respondents expressed a positive rating for the statement 47.8% (agree) with a mean score of 4.19, and the respondents responses strongly affirm the results. Furthermore, the standard deviation (SD = 0.715) indicates some degree of variation in the responses from the participants.

Also in Table 4.1, production flexibility was evaluated by two statements. The first statement ‘‘my firm has the capacity to adjust its operations to deal with unforeseen occurrences’’. The statement received a positive rating from the majority of respondents 50% (agree), the mean score stands at 4.16, validating the findings. Moreover, the standard deviation (SD = 0.845) suggests a certain level of deviation in the responses from the participants. The second statement ‘‘my firm quickly adapts to changes particularly consumer wants and expectations’’. Majority of respondents rated the statement positively 44.1 (agree), the validity of this result is supported by a mean score of 4.19. Additionally, the standard deviation (SD = 0.725) indicating some level of variation in respondents' answers.

Table 4.1 further, establishes findings for the evaluation of product quality through two statements. The first statement ‘‘my firm´s product quality has promoted consumer loyalty’’ majority of respondents rated the statement positively (49.3%) who expressed agreement, the validity of this result is supported by a mean score of with an average score of 4.18. In addition, the standard deviation (SD = 0.691) signifies a certain degree of variation in the responses from the participants. The second statement ‘‘My firm produces goods based on the market dynamics’’ having an average of 4.14 and a noteworthy response rate of 50.7% indicating agreement. Further, the standard deviation (SDV= .690) implies a variation in the responses from the participants. In general, there was consensus on the operational performance declarations, justified with an inclusive mean of 4.18 with 0.717 standard deviation, implying a certain degree of variability among the statements. In the context of operational performance, a high mean value implies that, on average, respondents perceive positive or favorable aspects related to operational performance. The standard deviation indicates the extent to which individual responses vary from the mean. In this case, a standard deviation of 0.717 suggests that there is a noticeable degree of variability among respondents in their perceptions of operational performance.

Overall, the results imply that while there is a consensus on positive aspects of operational performance, there are variations in individual opinions, highlighting potential areas of divergence in how different individuals perceive or assess operational performance.

4.2 Effect of Product Design on Operational Performance

To accomplish the first objective of the study, which aimed to investigate the effect of product design on operational performance of Sugar Firms in Kenya. First, an analysis involving the Pearson product-moment correlation coefficient was performed to evaluate the potential association between product design and operational performance. The decision to begin the research by conducting a Pearson correlation analysis was strategically chosen to establish an initial understanding of the relationships between variables, thereby providing a foundational framework for the subsequent ANOVA analysis (Zikmund & Babin, 2015). This approach allows for the exploration of potential associations among key factors, facilitating a more comprehensive and informed interpretation of the ANOVA results and contributing to a more robust overall analysis of the specific objective under investigation (Meyers *et al*., 2016).

The approach used to address the first objective involved formulating a null, positing that "Product design has no significant effect relationship with operational performance of Sugar Firms in Kenya." This hypothesis was examined across four distinct sub-indicators of product design; e-manufacturing, quality function deployment, supply chain management, and digital technologies. The four sub-indicators of product design were individually correlated with operational performance, and bi-variate correlations were attained. Bivariate analysis, using Pearson correlation, was conducted to explore the relationships between the independent sub-indicators of product design and the dependent variable (operational performance). The independent sub-indicator variables, encompassing e-manufacturing, quality function deployment, supply chain management, and digital technologies, were regressed against operational performance. Finally, the overall product design variable was subjected to regression analysis with operational performance as the independent variable. The tested hypothesis was then concluded by calculating an overall mean and correlating it with operational performance. At a predefined value of 0.05, all correlations were declared to be significant. Table 4.2 presents the conclusions. Table 4.2 provides an illustration of the outcomes.

Table 4. 2: Relationship between Product Design and Operational Performance of Sugar Firms in Kenya

		Operational Performance
E-manufacturing	Pearson Correlation	.545**
	Sig. (2-tailed)	.000
	N	136
Quality Function Deployment	Pearson Correlation	.607**
	Sig. (2-tailed)	.000
	N	136
Supply Chain Management	Pearson Correlation	.636**
	Sig. (2-tailed)	.000
	N	136
Digital Technologies	Pearson Correlation	.315**
	Sig. (2-tailed)	.000
	N	136
Product Design	Pearson Correlation	.742**
	Sig. (2-tailed)	.000
	N	136

**. Correlation is significant at the 0.05 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Source: Survey Data 2023

E-manufacturing exhibited a somewhat positive association with operational performance (r=0.545, p=.000), suggesting that e-manufacturing sub-indicator of product design is linked to high levels of operational performance. The correlation between quality function deployment and operational performance demonstrated a statistically significant and moderately positive correlation (r=0.607, p=.000). The correlation between supply chain management and operational performance was found to be moderate and positive (r=0.636, p<0.001). The strength of the correlation between digital technologies and operational performance was found to be weak. This is in agreement with the Kenya Association of Manufacturers, (2020) Strategic Plan 2021-2025, that postulated that the sugar subsector in

Kenya is experiencing high cost and product inefficiencies across the value chain because of utilization of obsolete technology. As evidence in his research investigation, the Pearson product-moment correlation between digital technologies and operational performance was found to ($r=0.315$, $p<0.001$). This indicates that although the extent of digital technology implementation was somewhat modest, there existed a marginally elevated degree of operational performance, leading to a subtle connection between these factors. The final results indicated an overall noteworthy and positive connection between product design and operational performance ($r=0.742$, $p<0.001$), suggesting that the application of product design by Sugar Firms in Kenya can be linked to high levels of operational performance. As a result, the null hypothesis was rejected in favor of the alternative hypothesis, which suggests a positive and noteworthy connection between product design and operational performance. Therefore, the adoption of product design in the production line of Kenya Sugar Firms is associated with improved operational performance.

Further, in pursuit of the first objective, the following sub-indicators were used to measure product design e-manufacturing, quality function deployment, supply chain management, and digital technologies. Table 4.3 presents frequency counts, percentages, averages, and standard deviation based on a 5-point Likert scale, where 1 signifies the strongest disagreement and 5 indicates the being the strongest agreement.

Table 4. 3: Product Design

Statement	SD f (%)	D f (%)	N f (%)	A f (%)	SA f (%)	MEAN	SD
E-manufacturing has enabled my company to benefit from digital transformation			22(16.2)	76(55.9)	37(27.2)	4.10	.676
The adoption of e-manufacturing has improved productivity and efficiency in my firm.			27(19.9)	61(44.9)	48(35.3)	4.15	.729
Quality function deployment has helped my company to define customer satisfaction and translate those customer desires into the target design			28(20.6)	54(39.7)	52(38.2)	4.15	.794
Quality function deployment has improved customer satisfaction			23(16.9)	62(45.6)	50(36.8)	4.18	.732
Supply chain management has reduced operating expenses arising throughout the supply chain in my firm			22(16.2)	65(47.8)	49(36.0)	4.20	.697
My firm practices integrated supply chain links that allow collaboration and simultaneous product design between suppliers and manufacturers			26(19.1)	53(39.0)	57(41.9)	4.23	.750
Digitalization has resulted in increased			13(9.6)	71(52.2)	52(38.2)	4.29	.631

Statement	SD f (%)	D f (%)	N f (%)	A f (%)	SA f (%)	MEAN	SD
efficiency in production in my firm							
Digital technology has improved and optimized manufacturing systems in my firm			19(14.0)	64(47.1)	53(39.0)	4.25	.686

Source: Survey data, (2023)

The outcomes presented in Table 4.3 suggests that adoption of e-manufacturing enabled sugar firms to benefit from digital transformation. 55.9% of respondents expressing agreement with this statement and the mean score stands at 4.10, validating the findings. Also, the standard deviation (SD = 0. 676) suggests some variations in the responses from the participants. In the second statement, adoption of e-manufacturing improved productivity and efficiency of sugar firms. 44.9% of respondents expressed agreement with this statement and the results were confirmed by a mean score of 4.15. Also, the standard deviation (SD = 0. 729) suggests some variations in the responses from the participants. Based on the perspectives of the respondents, it was observed that quality function deployment helped sugar firms to define customer satisfaction and translate the customer desires into the targeted design with 39.7% of respondents expressing agreement with this statement and the mean score stands at 4.15, validating the findings. Also, the standard deviation (SD = 0. 794) suggests some variations in the responses from the participants. This finding was closely aligned with quality function deployment improved customer satisfaction with 45.6% of respondents expressed agreement with this statement and the mean score stands at 4.18, validating the findings. Also, the standard deviation (SD = 0. 732) suggests some variations in the responses from the participants.

Besides that, respondents approved that the adoption of supply chain management resulted in reduced operating expenses throughout the supply chain, as evidenced by the largest proportion of participants, (47.8%) who agreed and the mean score stands at 4.20, validating the findings. Also, the standard deviation (SD = 0. 697) suggests some variations in the responses from the participants. In addition, integration of supply chain links enabled collaborative efforts and simultaneous product design between suppliers and manufacturers, majority of respondents expressed a positive rating for the statement 41.9% (strongly agree) with a mean score of 4.23, justifying that respondents' responses strongly affirm the results. Also, the standard deviation (SD = 0. 750) suggests some variations in the responses from the participants. Subsequently, the results also unveiled that digitalization resulted in increased efficiency of production in sugar firms with 52.2% of respondents expressed agreement with this statement and the mean score stands at 4.29, validating the findings. Also, the standard deviation (SD = 0. 631) suggests some variations in the responses from the participants. Further, the results also unveiled that digitalization improved and optimized manufacturing systems in the Sugar firms with 47.1% of respondents expressed agreement with this statement and the mean score stands at 4.25, validating the findings. Also, the standard deviation (SD = 0. 686) suggests some variations in the responses from the participants. Table 4.4 provides the model's results.

Table 4. 4: Model Significance for the Relationship between Lean Manufacturing Practices and Operational Performance

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.577	1	3.577	164.101	.000[b]
	Residual	2.921	134	.022		
	Total	6.498	135			

a. Dependent Variable: Operational Performance

b. Predictors: (Constant), Product Design

Source: Survey data, (2023)

The outcomes presented in Table 4.4 indicate that the model is statistically noteworthy at the 0.05 alpha level, with an F-statistic of 164.101. This implies that the null hypothesis of the model is rejected to uphold the alternative hypothesis, indicating a meaningful connection between the independent variable (product design) and operational performance within the studied population.

Hence, the chosen model is considered suitable for investigating the research hypothesis. Subsequently, a summary of the research hypothesis model results was presented to assess how product design may potentially influence operational performance. This presentation is depicted in Table 4.5.

Table 4. 5: Summary Model for the Percentage Change in Operational Performance Explained by Product Design

Model Summary[b]

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.742[a]	.550	.547	.14764	.550	164.101	1	134	.000

a. Predictors: (Constant), Product Design

b. Dependent Variable: Operational Performance

Source: Survey data, (2023)

The findings presented in Table 4.5 reveal that product design accounted for 55.0% of the variance in operational performance [R square=0.550, F=164.101, p=0.000]. This implies that product design explain 55.0% of the observed variability in operational performance of Kenya Sugar Firms. In the context of this study, the F-Statistic (F) holds a value of 164.101. The F-statistic is an essential tool for evaluating the comprehensive significance of the regression model (Lipson, 2020). This observation suggests that when the F-value is larger, as evidenced by the substantial F-Statistic value, the predictor variable (product design) plays a considerable role in elucidating the variations observed in the dependent variable (operational performance). In essence, the prominence of the F-value underscores the increasing likelihood that the link between product design and operational performance carries substantial positive statistical significance. Further, Table 4.6 portrays results concerning the effect of product design on operational performance.

Table 4. 6: Estimated Regression Coefficients for the Effect of Product Design on Operational Performance

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	1.017	.248		4.106	.000
	Product Design	.747	.058	.742	12.810	.000

a Dependent Variable: Operational Performance:

Source: Survey data, (2023)

The coefficient outcomes in Table 4.6 demonstrated that product design is statistically significant and positively connected with operational performance (β=0.742, p=0.000). Hence, according to the findings, a one-standard deviation increase in product design would result in a positive 0.742 unit change in operational performance in the absence of any other variable. This implies that the null hypothesis was rejected to uphold the alternative hypothesis, indicating a meaningful connection between the independent variable (product design) and operational performance. Therefore, the adoption of product design in the production system of Kenya Sugar Firms is associated with improved operational performance. Additionally, the study aimed to assess whether the model could elucidate a noteworthy alteration in operational performance when incorporating lean manufacturing as a variable.

The outcomes of this scholarly enquiry are aligned alongside the findings of a prior investigation conducted by Kariuki, (2016); Roble and Wanjira, (2021); Ahmad *et al*. (2018) and Bagshaw, (2017) confirmed the presence of a positive correlation between product design and operational performance. However, it is worth noting that the prior research approaches have been criticized. A study conducted by Kariuki, (2016), showed a strong relationship with an R-squared value of 0.767 ($p = 0.002$). Nevertheless, it did not include a moderator variable to investigate how a moderator might impact this relationship. Besides that, a study conducted by Gao *et al*., (2021) demonstrated a weak association of ($\beta = 0.27$, $p < 0.001$) as compared to the present research which demonstrated a more positive and significant connection between variables. Ahmad *et al*. (2018) adopted a questionnaire method to gather data from 400 respondents and out of which only 80 responded representing 20% of the target population. This is a small response rate (20%) meaning that the study suffered 80% nonresponse biasness of hence commemorating to biased conclusions. Further, the study registered a weaker association ($r = 0.570$, $p < 0.05$).

Bagshaw, (2017) the research was drawn from a sample size of 28 production managers of manufacturing firms in Nigeria. The research focused on a confined geographical area which might limit the applicability of the study's findings to a broader context. Further, Bagshaw, (2017) established a weak association of (PV=0.000<0.05, t-cal=5.559>t-tab (0.05, 27)=2.05) as compared with the current study's result ($\beta=0.742$, $p=0.000$) which demonstrated a more significant and interpretable relationship between variables, supported by a strong effect size and a highly significant p-value. Indeed it is worth noting that the current study employed unique metrics: e-manufacturing, quality function deployment, supply chain management, and digital technologies, to measure product design. These unique measures allowed for a more comprehensive assessment of how product design affects operational performance, providing valuable insights into specific aspects that contribute to favorable outcomes. By incorporating these unique metrics, this research enriches the existing knowledge hub by providing a more nuanced view of the relationship between product design and operational success in the context of Sugar Firms in Kenya by including these distinctive indicators. The research outcomes enhance the current body of knowledge, thereby, offering potential contributions to the refinement of both the resource based view and transaction cost theory that anchored the study. By establishing a notable and positive correlation between product design and operational performance, the study underscores the importance of strategic resource allocation and efficient transaction management within the context of sugar firms in Kenya.

Further, Table 4.7 portrays results concerning the effect of e-manufacturing, quality function deployment, supply chain management, and digital technologies on operational performance.

Table 4. 7: Estimated Regression Coefficients for E-Manufacturing, Quality Function Deployment, Supply Chain Management, and Digital Technologies, on Operational Performance

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	1.038	.243		4.265	.000
	E-manufacturing	.198	.047	.267	4.173	.000
	Quality function deployment	.212	.054	.281	3.948	.000
	Supply chain management	.241	.051	.337	4.679	.000
	Digital technologies	.093	.035	.154	2.637	.009

a. Dependent Variable: Operational Performance

Table 4.7 demonstrated the relationship between various sub-indicators of the independent variable (product design) (e-manufacturing, quality function deployment, supply chain management, digital technologies) and their impact on the dependent variable (Operational Performance) to establish their respective capacity to effectively evaluate product design. The constant value (β) is 1.038, and it is statistically significant (p = .000). This represents the expected value of the dependent variable (Operational Performance) when all independent variables are zero.

This research investigated the effect of e-manufacturing on operational performance within the context of Sugar Firms in Kenya. This research sought to establish how the implementation of e-manufacturing affects operational performance and its capacity to effectively evaluate product design. Table 4.7 demonstrated that e-manufacturing is statistically significant and positively connected with operational performance (β=0.267, p=0.000). Hence, according to the findings, a one-standard deviation increase in e-manufacturing would result in a positive 0.267 unit change in operational performance in the absence of any other variable. Therefore, the adoption and enhancement of e-manufacturing techniques appear to yield a substantial positive impact on the operational performance. This finding not only contributes valuable insights to the specific context of the sugar industry but also underscores the broader relevance of e-manufacturing strategies in the realm of operational performance and product design assessment.

This research further investigated the effect of quality function deployment on operational performance within the context of Sugar Firms in Kenya. This research sought to establish how the implementation of quality function deployment affects operational performance and its capacity to effectively evaluate product design. Table 4.7 demonstrated that quality function deployment is statistically significant and positively connected with operational performance (β=0.281, p=0.000). Hence, according to the findings, a one-standard deviation increase in quality function deployment would result in a positive 0.281 unit change in operational performance in the absence of any other variable. Therefore, the adoption and enhancement of quality function deployment appear to yield a substantial positive impact on the operational performance. This finding not only contributes valuable insights to the specific context of the sugar industry but also underscores the broader relevance of quality function deployment in the realm of operational performance and product design assessment.

This research additional investigated the effect of supply chain management on operational performance within the context of Sugar Firms in Kenya. This research sought to establish how the implementation of supply chain management affects operational performance and its capacity to effectively evaluate product design. Table 4.7 demonstrated that supply chain management is statistically significant and positively connected with operational performance (β=0.337, p=0.000. Hence, according to the findings, a one-standard deviation increase in supply chain management would result in a positive 0.337 unit change in operational performance in the absence of any other variable. Therefore, the adoption and enhancement of supply chain management appear to yield a substantial positive impact on the operational performance. This finding not only contributes valuable insights to the specific context of the sugar industry but also underscores the broader relevance of supply chain management in the realm of operational performance and product design assessment.

This research subsequently investigated the effect of digital technologies on operational performance within the context of Sugar Firms in Kenya. This research sought to establish how the implementation of digital technologies affects operational performance and its capacity to effectively evaluate product design. Table 4.7 demonstrated that digital technologies is statistically significant and positively connected with operational performance (β=0.154, p=0.000). Hence, according to the findings, a one-standard deviation increase in digital technologies would result in a positive 0.154 unit change in operational performance in the absence of any other variable, though the relationship is weaker compared to the other variables. Therefore, the adoption and enhancement of digital technologies appear to yield a substantial positive impact on the operational performance. This finding not only contributes valuable insights to the specific context of the sugar industry but also underscores the broader relevance of digital technologies in the realm of operational performance and product design assessment.

This analysis indicates that e-manufacturing, quality function deployment, supply chain management, and to some extent digital technologies all have positive and statistically significant relationships with operational performance and they also constitute a robust metric to measure product design. Supply Chain Management revealed a strong positive and statistically significant effect on Operational Performance. Finally, digital technologies established a positive but less pronounced and marginally significant impact on Operational Performance. The integration of new metrics as indicated in Table 4.7, such as e-manufacturing, quality function deployment, supply chain management, and digital technologies, into the evaluation of product design further enriches the understanding of how firms can optimize their resources and minimize transaction costs to improve operational performance. This newfound insight challenges traditional assumptions and encourages scholars and practitioners to consider a more holistic approach to analyzing and enhancing firm performance.

By contributing empirical evidence to support and strengthen these theoretical frameworks, the study not only advances academic understanding but also offers practical implications for industry stakeholders. The insights gained from this research can be leveraged by sugar firms in Kenya and beyond to devise more effective strategies, optimize their production processes, and ultimately achieve better operational performance. As a result, the study's findings are instrumental in shaping the theoretical underpinnings and practical applications of the resource-based view and transaction cost theory, bringing about meaningful advancements in the field of organizational management and strategy.

4.3 Effect of Lean Manufacturing Practices on Operational Performance of Sugar Firms in Kenya

The second objective of the research was to evaluate the effect of lean manufacturing practices and operational performance of Sugar Firms in Kenya. To accomplish this goal, the initial step involved establishing the measurement of lean manufacturing, which was subsequently followed by testing the study's hypothesis. In pursuit of this objective, the following sub-indicators were used to measure lean manufacturing: continuous improvement, total productive maintenance, just-in-Time, and value stream mapping. The outcomes are depicted in Table 4.8 using frequency counts, percentages, means, and standard deviations. Responses were assessed using a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

Table 4. 8: Lean Manufacturing

Statement	SD f (%)	D f (%)	N f (%)	A f (%)	SA f (%)	MEAN	SD
Adoption of just-in-time has reduced manufacturing costs in my firm			15(11.0)	58(42.6)	63(46.3)	4.35	.673
Adoption of just-in-time has reduced the level of waste in my firm			26(19.1)	57(41.9)	53(39.0)	4.20	.739
Total productive maintenance has decreased the incidence of accidents in my firm		33(24.3)	20(14.7)	49(36.0)	34(25.0)	3.62	0.549
Total productive maintenance has made equipment operating conditions better in my firm			20(14.7)	56(41.2)	60(44.1)	4.29	.711
My firm utilizes continuous improvement to fostering a culture of efficiency, quality, and adaptability			22(16.2)	65(47.8)	49(36.0)	4.20	.697

Statement	SD f (%)	D f (%)	N f (%)	A f (%)	SA f (%)	MEAN	SD
My firm utilizes continuous improvement to drive operational excellence in its manufacturing system			18(13.2)	71(52.2)	47(34.6)	4.21	.660
My firm utilizes value stream mapping to establish waste-producing sections			18(13.2)	73(53.7)	44(32.4)	4.19	.652
value stream mapping facilitates formation for possible solutions to minimize and eliminate waste in my firm			16(11.8)	69(50.7)	51(37.5)	4.26	.655

Source: Survey Data (2023)

Table 4.8's outcomes have demonstrated a strong support among the respondents over the adoption of just-in-time in the reduction of manufacturing costs evident through the highest proportion, (46.3%) who strongly agreed with a mean score of 4.35, confirming the results. Also, the standard deviation (SD = 0. 673) suggests some variations in the responses from the participants. In addition, in the second statement adoption of just-in-time reduced the level of waste, majority of respondents expressed a positive rating for the statement 41.9% (agree) and the mean score stands at 4.20, validating the findings. Further, the results also unveiled that total productive maintenance decreased the incidence of accidents in the Sugar firms with 36.0% of respondents expressed agreement with this statement and the mean score stands at 3.62, validating the findings. Based on the perspectives of the respondents, it was observed that total productive maintenance has made equipment operating conditions better in the Sugar firms as established by 44.1% of the respondents who strongly agreed. Sugar firms use machines to detect waste and faults in the manufacturing system demonstrated a notable rating with a mean score of 4.20 and a significant response of 47.8% (agreed). This finding was closely aligned with Sugar Firms' use of machines to detect faults in the manufacturing system with 52.2% of respondents expressed agreement with this statement and the mean score stands at 4.21, validating the findings, as depicted in Table 4.3. Besides that, 53.7% of the respondents were in agreement that sugar firms utilize value stream mapping to establish waste-producing sections, as indicated by a robust mean score of 4.16, which strongly supports the obtained outcomes. Finally, 50.7% of the respondents also were in agreement that value stream mapping facilitates the formation of possible solutions to minimize and eliminate waste in the sugar firms, with a mean score of 4.19, seconding the findings.

The findings from Table 4.8 demonstrated strong approval from the respondents regarding adoption of just-in-time for reducing production costs and waste, as well as the effectiveness of total productive maintenance in improving equipment operating conditions and reducing accidents in the Sugar firms. The results also highlight the significant use of machines for detecting waste and faults in the manufacturing system, along with the implementation of value stream mapping to identify and address waste-producing sections, providing valuable insights for improving operational efficiency and resource utilization in the sugar sector.

In pursuit of the research’s second objective, the researcher examined a null hypothesis: "Lean manufacturing practices have no significant effect on the operational performance of Sugar Firms in Kenya." The relationship between the scores of lean manufacturing practices and operational performance was investigated using Pearson product-moment correlation, with overall mean being used as the starting point. In order to ascertain the presence of a correlation between lean manufacturing and operational performance, a Pearson product-moment correlation coefficient was performed. The decision to begin the research by conducting a Pearson correlation analysis was strategically chosen to establish an initial understanding of the relationships between variables, thereby providing a foundational framework for the subsequent ANOVA analysis (Zikmund & Babin, 2015). This approach allows for the exploration of potential associations among key factors, facilitating a more comprehensive and informed interpretation of the ANOVA results and contributing to a more robust overall analysis of the specific objective under investigation Meyers *et al.*, (2016).

Subsequently, a simple linear regression model was applied to regress how operational performance scores of related to lean manufacturing practices, aiming to determine the overall percentage change in operational performance attributed to implementation of lean manufacturing practices. The results of the correlation between lean manufacturing practices and operational performance are demonstrated in Table 4.9.

Table 4. 9: Correlation between Lean Manufacturing Practices and Operational Performance Practices

Correlations

		Lean manufacturing	Operational Performance
Lean manufacturing	Pearson Correlation	1	.661**
	Sig. (2-tailed)		.000
	N	136	136
Operational Performance	Pearson Correlation	.661**	1
	Sig. (2-tailed)	.000	
	N	136	136

**. Correlation is significant at the 0.01 level (2-tailed).

Source: Survey Data (2023)

Table 4.9 the results indicate that the Pearson product-moment correlation between lean manufacturing and operational performance exhibited a strong positive correlation that was statistically significant (r=0.661, p=0.000). As a result, the null hypothesis was rejected in favor of the alternative hypothesis, which suggests a positive and noteworthy connection between lean manufacturing and operational performance. This suggests that higher scores in lean manufacturing were associated with higher scores in operational performance for Sugar Firms in Kenya, indicating a substantial association amongst the two variables. To showcase this correlation, the Pearson product-moment correlation coefficient was employed, followed by the utilization of a simple linear regression model to evaluate the study's hypothesis. Before assessing the study's null hypothesis, the model's outcomes were initially examined to test its own null hypothesis. The null hypothesis of the regression model posits that "there is no significant association between any of the independent variables and the dependent variable within the population." This hypothesis is evaluated using the F-statistic obtained from the F distribution, commonly known as the F test.

In contrast, this current study stands out for its focus on the Sugar Subsector in Kenya, offering a valuable contribution to the existing knowledge. The established positive and noteworthy association between lean manufacturing and operational performance enhances and refines the resource-based view and transaction cost theory, which constituted a framework for this research. The findings underscore the importance of strategic resource allocation and efficient transaction management within the context of sugar firms in Kenya, providing valuable insights for the industry. Table 4.10 demonstrates the model's findings.

Table 4. 10: Model Significance for the Relationship between Lean Manufacturing Practices and Operational Performance

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.837	1	2.837	103.836	.000[b]
	Residual	3.661	134	.027		
	Total	6.498	135			

a. Dependent Variable: Operational Performance

b. Predictors: (Constant), Lean Manufacturing

Source: Survey data, (2023)

The findings presented in Table 4.10 suggest that the model holds statistical significance at the 0.05 alpha level, with an F-statistic of 103.836 for degrees of freedom (1, 135). The F-statistic, with a value of 103.836, is a pivotal measure for assessing the overall significance of the regression model. In this specific context, the noteworthy F-value underscores that the inclusion of the predictor variable (lean manufacturing) significantly contributes to explaining the variance observed in the dependent variable (operational performance). A higher F-value strengthens the likelihood of a meaningful relationship between lean manufacturing and operational performance. This implies that the null hypothesis was rejected to uphold the alternative hypothesis, indicating a meaningful connection between the independent variable (lean manufacturing) and operational performance of the research subjects. Hence, the model is therefore deemed appropriate for evaluating the study hypothesis. Subsequently, the summary model for study hypothesis results were presented for justification if lean manufacturing practices had an effect on operational performance, as illustrated in Table 4.11.

Table 4. 11: Summary Model for the Percentage change in Operational Performance Explained by Lean Manufacturing Practices

Model Summary[b]

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.661[a]	.437	.432	.16529	.437	103.836	1	134	.000

a. Predictors: (Constant), Lean manufacturing

b. Dependent Variable: Operational Performance

Source: Survey data, (2023)

The outcomes presented in Table 4.11 reveal a significant coefficient of determination (R^2 = 0.437, p = 0.000), indicating a significant and meaningful relationship between lean manufacturing practices and operational performance. This indicates that approximately 43.7% of the observed variability in operational performance can be accounted for by variations in the lean manufacturing practices. After correcting for any underestimation or overestimation of R2 outcomes, an adjusted R square value of 0.432 was determined (Adjusted R^2 = 0.432, p = 0.000). To better understand the percentage change in operational performance explained by lean manufacturing practices, a value of 43.2% was obtained by multiplying the R square value by 100%.

The research analysis report provides compelling evidence to reject the null hypothesis which states that "Lean manufacturing practices have no significant effect on operational performance of Sugar Firms in Kenya." The findings demonstrate a significant coefficient of determination (R^2 = 0.437, p = 0.000), indicating a strong and positive association between lean manufacturing practices and operational performance. The adjusted R square value of 0.432 further confirms this relationship after considering the potential underestimation or overestimation of the results.

The adjusted R square value of 0.432 translates to 43.2% when multiplied by 100%. This means that lean manufacturing practices alone can account for 43.2% of the variance in operational performance. Such a high percentage demonstrates that lean manufacturing practices have a noteworthy effect on the operational performance of Kenyan sugar firms.

Given these significant findings, the research analysis report supports the alternative hypothesis, suggesting that lean manufacturing practices do have a substantial influence on operational performance in the context of Sugar Firms in Kenya. Therefore, the investigation concludes that adopting lean manufacturing practices may result in enhanced operational performance in the Sugar Subsector, underscoring the importance of implementing these practices in the manufacturing system of Sugar Firms in Kenya. To gain further insights into the exceptional contribution of lean manufacturing on operational performance, additional results for the model coefficients were revealed in Table 4.12.

Table 4. 12: Estimated Regression Coefficients for the relationship between Lean Manufacturing and Operational Performance

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Correlations Zero-order	Correlations Partial	Correlations Part
1	(Constant)	1.503	.264		5.701	.000			
	Lean manufacturing	.637	.063	.661	10.190	.000	.661	.661	.661

a. Dependent Variable: Operational Performance:

Source: Survey data, (2023)

It is apparent given the findings in Table 4.12, demonstrated that lean manufacturing is statistically significant and positively connected with operational performance ($\beta = 0.661$, $p = 0.000$). This implies that the null hypothesis was rejected to uphold the alternative hypothesis, indicating a meaningful connection between the independent variable (lean manufacturing) and operational performance. This suggests that when both lean manufacturing and operational performance are standardized on the same scale and subjected to regression analysis, lean manufacturing shows a unique and impactful effect on operational performance.

The beta value of 0.661 indicates the extent by which operational performance scores would increase positively, equivalent to a unit change in lean manufacturing practices. In practical terms, this means that when Sugar Firms in Kenya consistently implement and execute lean manufacturing practices, there will be a notable increase in operational performance. In conclusion, the study results demonstrate the importance of lean manufacturing practices in driving operational performance for Sugar Firms in Kenya. The significant relationship and positive beta value highlight the potential benefits of adopting and maintaining lean manufacturing practices to enhance overall operational efficiency.

The results of this investigation mirrored earlier studies conducted by Buer *et al*. (2021); Hernandez-Matias *et al*. (2019); Kunyoria (2018); Malonza (2014); Nawanir (2016); Seng *et al*. (2021) who examined the association between lean manufacturing and operational performance. According to those studies, the concurrence was that lean manufacturing is statistically significant and positively connected with operational performance.

However, it is worth noting that the prior research approaches have been criticized. Buer *et al*. (2021); Hernandez-Matias *et al*. (2019); Nawanir, (2016) utilized web surveys, which are prone to introduce bias and affect the accuracy of the conclusions. Buer *et al*. (2021) study result ($\beta = 0.444$, $p = 0.005$) demonstrated significance, but the higher p-value suggests a slightly less confident level of significance. Similarly, Seng *et al*. (2021) study results (R square is 0.644, Durbin-Watson is 2.312) provided an R-squared value that indicated meaningful explained variance but did not offer insight into the statistical significance of the relationship. Moreover, the studies conducted by Kunyoria (2018); Malonza (2014) focusing on South Nyanza Sugar Company, Awendo Kenya and Mumias Sugar Company Limited, Kenya respectively, used relatively small case studies. Consequently, the outcomes might not be readily applicable to other contexts, limiting the generalizability of their findings. Moreover, Kunyoria's (2018) study result ($\beta=0.672$, $p = 0.037$) indicates a significant relationship as well, but the proximity of the p-value to the significance threshold suggests a slightly weaker level of confidence.

Furthermore, none of the reviewed studies incorporated all the following essential lean manufacturing practices to constitute a cohort metric to measure LM: total product maintenance, just-in-time, continuous improvement, and value stream mapping proposed by (Rocha-Lona *et al*., 2013). This oversight could have influenced the effect of lean manufacturing on operational performance in those studies. Finally, only two of the reviewed studies Malonza (2014) and Kunyoria (2018) did take Sugar Subsector as a case study hence forming a basis for this study in this subsector. This study's findings make a valuable contribution to the existing knowledge and have the potential to enhance and refine the resource-based view and transaction cost theory, which served as the guiding frameworks for this research. By establishing a positive and significant association between lean manufacturing and operational performance, the research highlights the importance of strategic resource allocation and efficient transaction management within the context of sugar firms in Kenya.

4.4 Moderating Effect of Lean Manufacturing Practices on the Relationship between Product Design and Operational Performance

The research's third objective aimed at exploring the moderating effect of lean manufacturing on the relationship between product design and operations management of Sugar Firms in Kenya. Although prior researchers have explored the correlation between product design and operational performance, these inquiries incorporated different moderating variables. However, the inclusion of lean manufacturing as a moderating factor was lacking, and the observed moderating effect was relatively weak. Hence, this research aims to address research gap by exploring the potential moderating role of lean manufacturing in this context. Table 4.13 shows the model summary statistics.

Table 4. 13: Summary Results of the Effect of Lean Manufacturing on the Relationship between Product Design and Operational Performance

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.742[a]	.550	.547	.14764	.550	164.101	1	134	.000
2	.850[b]	.723	.717	.11674	.173	41.166	2	132	.000

a. Predictors: (Constant), Product Design
b. Predictors: (Constant), Product Design, Lean Manufacturing
c. Dependent Variable: Operational Performance

Source: Survey data, (2023)

The summarized outcomes of the model, presented in Table 4.13, indicated that, when the moderating variable (lean manufacturing) is taken into account, the model can explain an additional 17.3% of the variance in operational performance (change in R-squared = 0.173, p = 0.000). Lean manufacturing had a positive and significant effect on the connection between product design and operational performance, the interaction term (specifically, the joint effect between lean manufacturing and product design) which represents the computed shared variance was not taken into account.

To address this, the study pursued its final objective by testing the hypothesis that "Lean manufacturing practices have no significant moderating influence on the relationship between product design and operational performance of Sugar Firms in Kenya." Hierarchical multiple regressions were employed to examination this hypothesis, using the scores of product design, lean manufacturing and operational performance. Operational performance was subjected to regression analysis involving the two variables stepwise. In the first step, the model included product design to evaluate its individual impact on operational performance. In the second step, it involved reintroducing lean manufacturing to determine if the model still had a notable impact on operational performance. The third model, entailed incorporation of the interaction term (lean manufacturing * product design) to ascertain if lean manufacturing moderates the relationship between product design and operational performance. In Table 4.14, the overall results of the model are displayed.

Table 4. 14: Summary Model Results for the Moderating Effect of Lean Manufacturing on the Relationship between Product Design and Operational Performance.

Model Summary[d]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.742[a]	.550	.547	.14764	.550	164.101	1	134	.000
2	.850[b]	.723	.717	.11674	.173	41.166	1	133	.000
3	.855[c]	.731	.723	.11543	.008	3.992	1	132	.048

a. Predictors: (Constant), Product Design
b. Predictors: (Constant), Product Design, Lean Manufacturing
c. Predictors: (Constant), Product Design, Lean Manufacturing, interaction term
d. Dependent Variable: Operational Performance

Survey data, (2023)

The results shown in Table 4.14 show that product design significantly contributed to the model and accounted for 55.0% of the variability in operational performance [R-squared = 0.550, F(1, 134) = 164.101, p = 0.000]. When lean manufacturing was introduced, the model elucidated an additional 17.3% of variability in operational performance [R square change=0.173, F (2,132) =41.166, p=0.000]. Finally, the inclusion of the interaction term (lean manufacturing * product design) in the final model (model 3) resulted in the model explaining 0.8% of variability in the dependent variable, operational performance [R square change=0.008, F (1, 131) = 3.992, p=0.048].

The research utilized the F-statistic to gauge the impact of the moderator effect and registered a value of 3.992. This statistic aided in evaluating whether lean manufacturing, as a moderator, significantly strengthens the model's capacity to explain the variance observed in operational performance when considered in conjunction with product design. The F-value of 3.992 hints that the incorporation of lean manufacturing as a moderator does exert some discernible effect on the model's explanatory capabilities.

Further, although the variance is small, it is confirming the presence of moderation and detecting interaction effects in social science research can be challenging due to typically small sample sizes, as discussed by Aiken *et al.*, (1991). Based on the study's findings, it suggest that lean manufacturing demonstrated a robust moderating effect on the relationship between product design and operational performance. The subtle shift in R square change, the moderately notable F-value, and the marginally significant p-value allude to the nuanced influence of lean manufacturing in enhancing the model's explanatory capabilities within the context of product design and operational performance interplay. This implies that the null hypothesis of the model is rejected to uphold the alternative hypothesis. This signifies that the moderator variable (lean manufacturing) positively and significantly impacts the interplay between product design and operational performance among Sugar Firms in Kenya. This suggests that in addition to current product design initiatives, Sugar Firms might enhance operational effectiveness by implementing lean manufacturing practices.

The analysis and presentation of the ANOVA findings in Table 4.15 aimed to ascertain the significance of the model.

Table 4. 15: Model Significance

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.577	1	3.577	164.101	.000[b]
	Residual	2.921	134	.022		
	Total	6.498	135			
2	Regression	4.699	3	1.566	114.937	.000[c]
	Residual	1.799	132	.014		
	Total	6.498	135			
3	Regression	4.752	4	1.188	89.155	.000[d]
	Residual	1.746	131	.013		
	Total	6.498	135			

a. Dependent Variable: Operational Performance
b. Predictors: (Constant), Product Design
c. Predictors: (Constant), Product Design, Lean Manufactured
d. Predictors: (Constant), Product Design, Lean Manufacturing, interaction term

Survey data, (2023)

Considering the F-test and the associated significance values presented in Table 4.15, it is evident that the model's significance outcomes indicate the statistical significance of all three models.

The demonstrated outcomes are F=164.101, p=0.000 for the predictor variable (product design), F=114.937, p=0.000 for the moderator variable (lean manufacturing) and F=89.155, p=0.000 for the dependent variable (operational performance) underline the intricate web of relationships between product design, lean manufacturing, and operational performance.

With an F-statistic of 164.101 and an associated p-value of 0.000, the inclusion of product design as a predictor variable significantly enhances the model's explanatory capacity. The F-statistic evaluates whether the predictor variable's addition contributes significantly to the model's ability to explain the variations in the dependent variable, operational performance. The substantial F-value highlights that product design holds considerable importance in clarifying the variances within operational performance. The p-value reinforces the statistical significance of this inclusion, suggesting that the likelihood of observing such a relationship by chance is virtually non-existent. In essence, product design plays a pivotal role in understanding and predicting operational performance within the studied context.

Incorporating lean manufacturing as a moderator, the analysis yields an F-statistic of 114.937, accompanied by a p-value of 0.000. This outcome signifies the statistical significance of lean manufacturing's role as a moderator in the relationship between product design and operational performance. The F-statistic emphasizes that lean manufacturing, when considered in a moderating context, substantially augments the model's ability to elucidate the fluctuations in operational performance linked to product design. The p-value reinforces the rarity of observing such a strong moderator effect by chance, further strengthening the robustness of this inclusion. This underscores that lean manufacturing's role as a moderator is statistically meaningful, holding potential implications for understanding how it influences the interaction between product design and operational performance.

With an F-statistic of 89.155 and a corresponding p-value of 0.000, the dependent variable, operational performance, is substantiated as a crucial element in the model. The F-statistic underscores that the chosen predictor and moderator variables collectively contribute significantly to explaining the variations within operational performance. The p-value affirms that the observed association between these variables and operational performance is highly unlikely to be random chance. Thus, operational performance stands as a central aspect in the model, with its fluctuations being closely tied to both product design and the moderating influence of lean manufacturing.

These results signify the substantial contributions of each variable to the model's capacity to explain the observed variations. Further reinforced by their highly significant F-values and extremely low p-values. This study's findings enhance the concept how these factors interplay, paving the way for informed decisions within the studied domain.

The study proceeded to present the model's coefficient outcomes, which are shown in Table 4.16, after determining the model's significance.

Table 4. 16: Estimated Regression Coefficients for Variables in the Effect of Lean Manufacturing on the Relationship between Product Design and Operational Performance

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	1.017	.248		4.106	.000
	Product Design	.747	.058	.742	12.810	.000
2	(Constant)	.190	.219		.867	.043
	Product Design	.349	.064	.346	5.464	.000
	Lean Manufacturing	.602	.068	.563	8.900	.000
3	(Constant)	.032	.231		.140	.015
	Product Design	.403	.069	.401	5.864	.000
	Lean Manufacturing	.646	.070	.605	9.172	.000
	Interaction term	.014	.007	.127	1.998	.048

a. Dependent Variable: operational performance

Source: Survey data, (2023)

To facilitate a comprehensive comparison regarding distinct variables, it is crucial to analyze the standardized coefficients, as opposed to the unstandardized coefficients. Standardized coefficients represent values that have been converted to a common scale, enabling a fair comparison across variables. On the other hand, unstandardized coefficients are used to construct a regression equation. When discussing standardized beta values, it is essential to describe the metric by which the scores in the dependent variable would alter, measured in standard deviations, due to a one-standard-deviation shift in the independent variable as discussed by Palant, (2005).

Table 4.16 presents the findings that indicate the effect of different variables on operational performance. In the absence of the independent variable (product design), unobserved factors are likely to lead to a 1.017 unit increase in operational performance, as denoted by the significant constant value. In model 1, upon introducing the first variable (product design) into the model, it demonstrated a positive statistically significant and substantial effect on operational performance (β=.742, p=.000). Further, when model 2 is added lean manufacturing also resulted in a positive statistically significant and substantial effect on operational performance (β=.563, p=.000). Finally, the interaction term (lean manufacturing * product design) was incorporated into the model, revealing a positive and significant effect on operational performance (β=.127, p=.048). Although the variance is small, it confirms the presence of moderation. Detecting interaction effects in social science research can be challenging due to the typically small sample sizes, as discussed by Aiken *et al*., (1991).

These results demonstrate that lean manufacturing exerts a moderating effect on the relationship between product design and operational performance. Specifically, one-unit increment in lean manufacturing, there is a corresponding positive increase of 0.127 units of operational performance. This implies that for Sugar Firms in Kenya to enhance their operational performance, they not only embrace product design initiatives but also consistently execute and implement lean manufacturing practices hence, the combination of indicators will lead to an overall increase in operational performance.

Moderating effects are stirred by variables whose discrepancy affects the quality of association among the independent and dependent variables (Baron & Kenny, 1986; Lai, 2013). The results of the moderating effects are termed "moderator variables" or "moderators" (Fassott *et al*., 2016). The moderation effect stipulates a way to analyze if the intervention leads to uniform outcomes among the groups Farooq and Vij, (2017). This study was guided by the moderating variable. This is due to the moderating variable's influence on the trajectory of an originator's effect on a result (Aguinis *et al*., 2017). The choice of a moderating variable should be informed on the basis of strong theoretical support (Farooq and Vij, 2017), hence this informed the choice of RBV and transaction cost theory.

Many investigations on moderation have employed alternative moderating factors ignoring lean manufacturing to explore the interplay between product design and operational performance. Gilal *et al*. (2018) in their study linking product design to consumer behavior adopted consumption experience as the moderator and did not address lean manufacturing as a moderator. They postulated a weak association of the moderator on the relationship between product design and consumer behavior (β=0.434, p=0.006). Lee and Johnson (2017) carried out a study on the effect of new product design and innovation on South Korean consumers' willingness to buy (WTB). They adopted individual innovativeness and individual product knowledge as independent moderators. Innovation in technology had a noteworthy moderating effect with respect to the association between new product design and willingness to buy ($F(1, 59) = 4.27$, $p<0.05$) postulated that the degree of technical innovation determines how to form design is guided on WTB radically new product or low on n incrementally new product.

Based on this, lean manufacturing may be used as a solution to these inconsistent outcomes and the poor correlations between product design and operational performance.

There is lack of specific investigation into the moderating influence of lean manufacturing on the association between product design and operational performance in the literature review. Though there are studies done that give a clue of a possible relationship among product design, lean manufacturing and operational performance having determined lean manufacturing as an architecture of product design and operational performance. For instance, a study by Gao *et al*., (2021) determining role of social media in an inspirational approach to product design and designer performance in Pakistan, established result of (β = 0.27, $p < 0.001$) indicating a weaker association between efficiency-focused product design and designer performance production system design. The weak association may be because the study failed to conduct the moderation effect. Besides that, Roble and Wanjira (2021) while writing on Effects of Product Design on Performance of Commercial Banks in Garissa County, Kenya failed to adopt a moderator and the study result (β=0.729 and ρ= 0.001) established a weak relationship, further, the case study was too small to be used for the purpose of generalization . Ahmad *et al*., (2018) focused on the impact of product design and process design on new product performance in the manufacturing industry utilized a nationwide sample comprising 100 Malaysian companies, the study adopted New Product and New process designs as independent variables with r= 0.092 and r= 0.570 results respectively. The study revealed a positive correlation (r=0.570) between new product process design and product performance. However, a significant relationship between new product design and product performance was not observed. This may have resulted because the study did not adopt a moderator.

In this context, the study offers a coherent rationale for the previously perplexing connection between product design and operational performance. Notably, the influence of lean manufacturing seems to moderate the correlation between product design and operational performance. A significant contribution lies in not only establishing this connection, but also delving into how lean manufacturing moderates it. Consequently, this research adds value by confirming and refining the current theory. Hence, this study presents a novel of lean manufacturing model with the capability to positively enhance the interplay between product design and operational performance.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter is divided into six sections, providing an overview of introduction, summary of the findings, closing statement, suggestions, list of limitations, and recommendations for further research. The primary aim of this research was to examine the relationship between product design, lean manufacturing and the operational performance of Sugar Firms in Kenya. The study aimed to achieve the following specific objectives: investigate the effect of product design on operational performance of Sugar Firms in Kenya, evaluate the effect of lean manufacturing practices on operational performance of Sugar Firms in Kenya and analyze the moderating influence of lean manufacturing practices on the relationship between product design and operational performance of Sugar Firms in Kenya.

5.1 Summary of the Findings

The first research objective aimed to investigate the effect of product design on operational performance of Sugar Firms in Kenya. This investigation involved four sub-indicators of product design, namely e-manufacturing, quality function deployment, supply chain management, and digital technologies. To determine the relationships between these sub-indicators and operational performance, Pearson product-moment correlation was utilized. The results revealed that supply chain management exhibited the strongest and most significant association with operational performance, followed by quality function deployment and operational performance. Additionally, there was a noteworthy relationship between e-manufacturing and operational performance, and a similar association was also observed between digital technologies and operational performance. These findings indicate that all four sub-indicators of product design are positively associated with the operational performance of Sugar Firms in Kenya.

The second research objective aimed to evaluate the effect of lean manufacturing practices on operational performance of Sugar Firms in Kenya. This analysis utilized a simple linear regression model to examine the relationship between lean manufacturing and operational performance. The results demonstrated a significant and positive effect of lean manufacturing on operational performance. Specifically, the outcomes indicated that lean manufacturing practices accounted for a considerable extent of the variability in operational performance. Moreover, the regression model revealed that a decrease in the adoption of lean manufacturing practices would result in a corresponding decrease in operational performance. These outcomes highlight the significant impact of lean manufacturing practices in augmenting operational performance for Sugar Firms in Kenya. The findings emphasize the importance of continuous execution and implementation of lean manufacturing initiatives to achieve enhanced operational performance.

Research objective three aimed to analyze the moderating influence of lean manufacturing practices on the relationship between product design and operational performance of Sugar Firms in Kenya. To achieve this objective, a hierarchical regression model was employed. The results of the analysis revealed that the moderating influence of lean manufacturing practices on the relationship between product design and operational performance is statistically significant. This implies that the interaction between lean manufacturing practices and product design plays a crucial role in shaping the impact of product design on operational performance. By uncovering this significant moderating effect, the research offers valuable comprehensions into the intricate dynamics between lean manufacturing practices, product design, and operational performance. These findings underscore the importance of considering lean manufacturing as a key factor in optimizing the effects of product design initiatives on operational performance for Sugar Firms in Kenya. Thus, the implementation of lean manufacturing practices alongside existing product design strategies can lead to enhanced operational performance.

5.2 Conclusions of the Study

Three conclusions were drawn from the study based on its objectives. For objective one, which focused on investigating the effect of product design on operational performance of Sugar Firms in Kenya, it was concluded that supply chain management played a more prominent role in determining product design compared to digital technologies which had the lowest prevalence in that regard. However, the study highlighted the importance of improving the dimension of digital technologies in product design to ensure a more robust and comprehensive approach to product design. This finding emphasizes the need for Sugar Firms to pay attention to enhancing their digital technologies capabilities to enhance their overall product design process. The study findings indicated a significant and positive relationship between all four sub-indicators of product design and operational performance among Sugar Firms in Kenya. This result suggests that a well-developed and comprehensive product design approach results to a noteworthy positive and statistically significant influences the operational performance of these firms.

Based on the second objective, ‘‘to evaluate the effect of lean manufacturing practices on operational performance of Sugar Firms in Kenya’’, the study established that lean manufacturing practices had a noteworthy positive and statistically significant influences operational performance. Consequently, it can be concluded that lean manufacturing is a crucial and influential factor in shaping the operational performance of Sugar Firms in Kenya.

From the final objective, which aimed to analyze the moderating influence of lean manufacturing practices on the relationship between product design and operational performance of Sugar Firms in Kenya, the study revealed that lean manufacturing significantly moderated the relationship between these variables. This indicates that as the adoption of lean manufacturing practices increases, in addition to the existing product design initiatives, operational performance also improves. In other words, lean manufacturing has a noteworthy positive and statistically significant influence on operational performance. The study concludes that lean manufacturing significantly moderates relationship between product design and operational performance, providing valuable insights for enhancing these aspects within the manufacturing context of Sugar Firms. By contributing a lean manufacturing model, this research adds to the existing knowledge base and provides a framework that can be utilized to strengthen the relationship between product design and operational performance, ultimately leading to improved operational performance outcomes for Sugar Firms in Kenya.

5.3 Recommendations of the Study

In reference to the first objective, which aimed to investigate the effect of product design on the operational performance of Sugar Firms in Kenya, the research implies the possibility of improving the comprehension of the construct of product design sub-indicators. To address this, it is recommended that Sugar Firms' Management focus on both operational performance and product design in their manufacturing systems. Paying special attention to supply chain management is essential for achieving high levels of product design. Therefore, it is advised that the management of Sugar Firms should prioritize and consistently work towards improving the aspects related to supply chain management. However, the study also revealed a weak relationship between digital technologies and operational performance. Therefore, it is crucial for Sugar Firms to place greater emphasis on the adoption of digital technologies in their manufacturing systems to effectively leverage a robust product design and ultimately enhance their operational performance. By doing so, the Sugar Firms can capitalize on the potential benefits that digital technologies offer and further optimize their operational performance.

The research's second objective focused on evaluating the effect of lean manufacturing practices on operational performance of Sugar Firms in Kenya. In reference the research outcomes, it is highly recommended that Sugar Firms prioritize and emphasize the utilization of lean manufacturing practices considering its strong positive interplay with operational performance. To achieve and sustain a high level of operational performance, the management of Sugar Firms should invest more resources and effort into adopting and continuously executing lean manufacturing practices. By doing so, Sugar Firms can effectively enhance their operational performance and achieve improved outcomes in their manufacturing processes.

Derived from the finding of the third research object, with a focus of analyzing the moderating influence of lean manufacturing practices on the relationship between product design and operational performance of Sugar Firms in Kenya, the study suggests that the management of Sugar Firms should reflect on enhancing the interplay between product design and operational performance. This might be accomplished by strategically blending, modifying, and aligning LM practices, which has demonstrated a positive and significant influence on this relationship. By effectively incorporating lean manufacturing practices into their product design and operational performance, Sugar Firms can foster a stronger and more beneficial connection between these two aspects, leading to improved overall operational performance and competitiveness in the industry.

5.4 Limitations of the Study

The research focused exclusively on four sub-indicators of product design; this approach may have constrained the researcher's ability to explore additional aspects, such as production iterations which could have provided insights to further elucidate the concept of product design. Design ethics and privacy in product design especially as technology becomes more integrated into products, ethical considerations related to user privacy and data security are gaining attention in the adoption of product design. The study was confined in Sugar Firms in Kenya only thus segregating other key sectors of the economy.

5.5 Suggestions for Further Studies

For future studies, the following recommendations are put forth to further enhance the understanding of the topics explored in this research:

1. Future research man be conducted regarding other manufacturing sectors like food and beverage, edible oils, chemicals, automotive, leather, and footwear sectors.
2. Future researcher may conduct longitudinal studies over an extended period would enable researchers to observe the long-term effects of product design and lean manufacturing practices on operational performance.
3. Future studies can delve into a more comprehensive range of product design sub-indicators, considering various sub-indicators such as eco-friendliness, production iterations, design ethics, and privacy considerations.
4. Future investigators may try to explore the effect of some specific LM tools like single-minute exchange of die, production smoothing, or andon to constitute a metric to measure LM.
5. In the future, researchers may investigate whether product design assumes the function of a moderator in establishing the relationship between lean manufacturing and operational performance.

By considering these suggestions, future research endeavors can advance a deeper comprehension of the dynamic relationship between product design, lean manufacturing, and operational performance, leading to more informed strategies for enhancing operational performance and competitiveness.

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APPENDICES

Appendix I: Introduction Letter

Dear Sir / Madam

Being a doctoral Candidate at Maseno University, I am enrolled in the School of Business and Economics under the Department of Management Science. I am undertaking research on product design, lean manufacturing and operational performance on of Sugar Firms in Kenya as part of the academic requirement. You've been recognized as a reliable participant to reflect on the current status of lean manufacturing as a moderator in the intricate relationship between product design and operational performance of Sugar Firms in Kenya, by filling in the attached questionnaire.

Using your best estimates, kindly reply to all the questions. Your assistance in answering the inquiries shall be greatly appreciated, and your answers will remain COMPLETELY CONFIDENTIAL. If you may have any queries, concerns or observations regarding this study, feel free to communication to me: Kunyoria Ogora Joseph of P.O. Box 103- 40404, Rongo; email: kunyoriaj@gmail.com and Phone No. : 0701529678.

I sincerely appreciate your participation and cooperation. Thank you.

Yours faithfully,

Kunyoria Ogora Joseph

Student – Maseno University

Appendix II: Informed Consent Release

Investigator:

"I am KUNYORIA OGORA JOSEPH, a Doctoral Student at Maseno University. You are hereby invited to contribute to this inquiry. Your participation in this study is at your own discretion, hence, you have the option to contribute or decline to participate. I am about to provide you with an overview of the study. Feel welcome to inquire about any aspects or request clarification regarding this research; it will be my pleasure to elaborate on anything in a detailed context.

"I am driven by the urge to discover more about *the relationship between product design, lean manufacturing and operational performance*. You are required to tick in appropriate boxes. This will require just about thirty minutes of your time. Each participant's information will be treated with *confidential*ity and will be kept *anonymous*. This indicates that your personal details (name and employment number amongst others) will not be required in this study and it's only me who will know your specific responses. A code will be allocated to your responses, and it's only me who will have rights to decide to allocate the codes to the research participants. I will use a make-up name for you in any articles I may write or any presentations that I make and I will not reveal any details or share with anyone your personal information amongst others.

"The solo advantage of this research study is that you will be assisting us to recognize the interplaying relationship among product design, lean manufacturing and operational performance of Sugar firms in Kenya. Its research findings will act as a basis for further research in the operations management discipline from the perspective of the product transformation process. To the practitioners, the findings will be of great importance as they will be able to understand the importance of adopting of lean manufacturing practices during product designing in the manufacturing system to elevate operational performance.

As a respondent, you are not exposed to any risks by participating in this research study. If you do not wish to continue with this research project, you may do so at any moment without incurring any fees."

Respondent:

“In my opinion questions and concerns about the research inquiry have just been courteously addressed. As a result, I like to voluntarily participate in this research study and affirm that I am older than 18.

Name of the respondent: ____

Signature of the respondent ________________________ Date _____________________

Name of the researcher ____

Signature of the Respondent ________________________ Date _____________________

Appendix III: Questionnaire

Declaration

This research study's key objective is to determine the association among **product design, lean manufacturing, and the operational performance of Kenyan sugar companies.**

Only academic goals will be served by the data collected through this survey, which must be handled with absolute confidentiality. Your contribution in relation to the study will be greatly valued.

Section A: Product Design

To what extent do you agree that your firm used the following product design practices to improve the overall operational performance?

Put an × in the relevant box

Key: 5:- SA = Strongly Agree, 4:- A= Agree, 3:- N = Neutral, 2:- D=Disagree and 1:- SD Strongly Disagree

STATEMENT	SA	A	N	D	SD
E-manufacturing has enabled my company to benefit from digital transformation					
The adoption of e-manufacturing has improved productivity and efficiency in my firm.					
Quality function deployment has helped my company to define customer satisfaction and translate those customer desires into the target design					
Quality function deployment has improved customer satisfaction					
Supply chain management has reduced operating expenses arising throughout the supply chain in my firm					
My firm practices integrated supply chain links that allow collaboration and simultaneous product design between suppliers and manufacturers					
Digitalization has resulted in increased efficiency in production in my firm					
Digital technology has improved and optimized manufacturing systems in my firm					

SECTION B_1: LEAN MANUFACTURING AND OPERATIONAL PERFORMANCE

To what extent do you agree that your firm used the following lean manufacturing practices an effort to improve the overall operational performance?

Put an × in the relevant box

Key: 5:- SA = Strongly Agree, 4:- A= Agree, 3:- N = Neutral, 2:- D=Disagree and 1:- SD Strongly Disagree

STATEMENT	SA	A	N	D	SD
Adoption of just-in-time has reduced manufacturing costs in my firm					
Adoption of just-in-time has reduced the level of waste in my firm					
Total productive maintenance has decreased the incidence of accidents in my firm					
Total productive maintenance has made equipment operating conditions better in my firm					
My firm utilizes continuous improvement to fostering a culture of efficiency, quality, and adaptability					
My firm utilizes continuous improvement to drive operational excellence in its manufacturing system					
My firm utilizes value stream mapping to establish waste-producing sections in my firm					
value stream mapping facilitates formation for possible solutions to minimize and eliminate waste in my firm					

SECTION B_2: LEAN MANUFACTURING PRODUCT DESIGN AND OPERATIONAL PERFORMANCE

To what extent do you agree that your firm used the following lean manufacturing practices to boost the relationship between product design and overall operational performance?

Put an × in the relevant box

Key: 5:- SA = Strongly Agree, 4:- A= Agree, 3:- N = Neutral, 2:- D=Disagree and 1:- SD Strongly Disagree

STATEMENT	SA	A	N	D	SD
My firm utilizes just-in-time practices in its manufacturing system to foster efficiency and optimize resource utilization					
My firm integrates total productive maintenance in its manufacturing system to enhanced innovation by fostering a culture of creativity.					
My firm practices continuous improvement in its manufacturing system to optimize workflows and enhance product quality					
My firm employs value stream mapping in its manufacturing system to enhance production processes.					

SECTION C: OPERATIONAL PERFORMANCE

To what extent do you agree that the following attributes affect your firm's operational performance?

Put an × in the relevant box

Key: 5:- SA = Strongly Agree, 4:- A= Agree, 3:- N = Neutral, 2:- D=Disagree and 1:- SD Strongly Disagree

STATEMENT	SA	A	N	D	SD
My firm produces goods at a price that allows them to be valued fairly in the market					
My firm utilizes technology to relevant technology to lower the cost of production					
My firm has the capacity to adjust its operations to deal with unforeseen occurrences					
My firm quickly adapts to changes particularly consumer wants and expectations					
My firm´s product quality has promoted consumer loyalty					
My firm produces goods based on the market dynamics					
My company delivers goods right on time					
My firm takes the shortest time to respond to commended production changes					
My firm responds to customer needs and orders as they arise					
My firm takes a minimum set time to produce goods per unit					

Appendix IV: Sample Frame

	Sugar factories Company	County	Ownership	status
1)	Miwani Sugar Company	Kisumu	Public	Under receivership
2)	Ramisi Sugar	Kwale	Private	Close
3)	Muhoroni	Kisumu	Public	Under receivership
4)	Chemelil Sugar Company	Kisumu	Public	Milling
5)	Mumias Sugar Company	Kakamega	Public	Under receivership
6)	Nzoia Sugar Company	Bungoma	Public	Milling
7)	West Kenya Sugar Company	Kakamega	Private	Milling
8)	Sony Sugar Company	Migori	Public	Milling
9)	Soin Sugar Company	Kericho	Private	Milling
10)	Kibos Sugar & Allied Industries Limited	Kisumu	Private	Milling
11)	Butali Sugar Mill limited	Kakamega	Private	Milling
12)	Transmara Sugar Company	Narok	Private	Milling
13)	Sukari Sugar Company	Homa-Bay	Private	Milling
14)	Kwale International Sugar Company	Kwale	Private	Milling
15)	Ole Pito Sugar Company	Busia	Private	Milling
16)	Busia Sugar Company	Busia	Private	Milling

Source: Kenya Association of Manufacturers, (2020)

Appendix V: Sample Size

Company	Department	Sample Size
Chemelil Sugar Company	Agriculture	2
	Marketing	2
	Finance	2
	Factory operations	2
	ICT	2
	Human Resource	2
	Quality Assurance	2
	Internal Audit	2
	Legal	2
	Supply Chain	2
Source: Chemilil Sugar Company, 2022		
Nzoia Sugar Company	Human Resource	2
	ICT	2
	Company Secretariat	2
	Internal Audit	2
	Agriculture	2
	Production	2
	Public Relations	2
	Procurement	2
	Finance	2
	Sales and Marketing	2
	Agriculture Services	2
Source: Nzoia Sugar Company, 2022		
Sony Sugar Company	Procurement	2
	Finance and Accounting	2
	ICT	2
	Agricultural	2
	General Administration	2
	Manufacturing	2
	Human Resource	2
	Sales and marketing	2
	Company secretariat	2
Source: Sony Sugar Company, 2022		
Butali Sugar Mills Limited	Agricultural	2
	Transport & Logistics	2
	Finance	2
	Human Resource	2
	Sales and Marketing	2
	ICT	2
	Administration	2
	Procurement & Stores	2
	Factory & Projects	2
Source: Butali Sugar Mills Limited, 2022		
Sukari Sugar Company	Engineering	2
	Process	2

	Agriculture	2
	Transport	2
	Finance	2
	ICT	2
	Auto workshop	2
	Mechanical	2
	Logistics	2
Source: Sukari Sugar Company		
Kibos Sugar & Allied Industries Limited	Finance	2
	Procurement	2
	Factory operations	2
	Stores	2
	Transport	2
	Production	2
	Human Resource	2
	Agriculture	2
	ICT	2
Source: Kibos Sugar & Allied Industries Limited, 2022		
West Kenya Sugar Company	Finance	2
	Factory operations	2
	Procurement	2
	Administration	2
	Agriculture	2
	ICT	2
	Transport	2
	Sales and Marketing	2
Source: West Kenya Sugar Company, 2022		
Ole Pito Sugar Company	Agriculture	2
	Factory operations	2
	Finance	2
	Internal Audit	2
	Sales and Marketing	2
	Transport	2
	Human Resource	2
	ICT	2
Source: Ole Pito Sugar Company, 2022		
Busia Sugar Company	Agriculture	2
	Procurement	2
	Transport	2
	ICT	2
	Finance and accounting	2
	Manufacturing	2
	Factory operations	2
	Sales and marketing	2
	Human Resource	2
Source: Busia Sugar Company, 2022		
Grand total		**164**

Appendix VI: Letter from School of Graduate Studies, Maseno University

MASENO UNIVERSITY

SCHOOL OF GRADUATE STUDIES

Office of the Dean

Our Ref: PHD/BE/00004/2019

Private Bag, MASENO, KENYA
Tel:(057)351 22/351008/351011
FAX: 254-057-351153/351221
Email: sgs@maseno.ac.ke

Date: 10th March, 2023

TO WHOM IT MAY CONCERN

RE: PROPOSAL APPROVAL FOR KUNYORIA OGORA JOSEPH— PHD/BE/00004/2019

The above named is registered in the Doctor of Philosophy in Operations Management programme in the School of Business and Economics, Maseno University. This is to confirm that his research proposal titled "Relationship between product Design Lean manufacturing and operational performance of sugar firms in Kenya" has been approved for conduct of research subject to obtaining all other permissions/clearances that may be required beforehand.

Prof. J.O. Agure
DEAN, SCHOOL OF GRADUATE STUDIES

Maseno University *ISO 9001:2008 Certified*

Appendix VII: Approval from Maseno University Scientific and Ethics Review Committee

MASENO UNIVERSITY SCIENTIFIC AND ETHICS REVIEW COMMITTEE

Tel: +254 057 351 622 Ext: 3050
Fax: +254 057 351 221

Private Bag – 40105, Maseno, Kenya
Email: muerc-secretariate@maseno.ac.ke

REF: MSU/DRPI/MUSERC/01220/23

Date: 29th May, 2023

TO: Kunyoria Ogora Joseph
PHD/BE/00004/2019
Department of Management Science
School of Business and Economics
Maseno University
P. O. Box, Private Bag, Maseno, Kenya

Dear Sir,

RE: Relationship between Product Design, Lean Manufacturing and Operational Performance of Sugar Firms in Kenya

This is to inform you that **Maseno University Scientific and Ethics Review Committee (MUSERC)** has reviewed and approved your above research proposal. Your application approval number is MUSERC/01220/23.The approval period is 29th May, 2023 – 28th May, 2024.

This approval is subject to compliance with the following requirements;

i. Only approved documents including (informed consents, study instruments, MTA) will be used.
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by Maseno University Scientific and Ethics Review Committee (MUSERC).
iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to Maseno University Scientific and Ethics Review Committee (MUSERC) within 24 hours of notification.
iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to Maseno University Scientific and Ethics Review Committee (MUSERC) within 24 hours.
v. Clearance for export of biological specimens must be obtained from relevant institutions.
vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.
vii. Submission of an executive summary report within 90 days upon completion of the study to Maseno University Scientific and Ethics Review Committee (MUSERC).

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and Innovation (NACOSTI) https://oris.nacosti.go.ke and also obtain other clearances needed.

Yours sincerely

MASENO UNIVERSITY ETHICS REVIEW COMMITTEE
29 MAY 2023

Prof. Philip O. Owuor, PhD, FAAS, FKNAS
Chairman, MUSERC

MASENO UNIVERSITY IS ISO 9001 CERTIFIED

Appendix VIII: Approval form NACOSTI

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Ref No: **608442**

Date of Issue: **22/June/2023**

RESEARCH LICENSE

This is to Certify that Mr.. Joseph Ogora Kunyoria of Maseno University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Bungoma, Busia, Homabay, Kakamega, Kisumu, Migori on the topic: RELATIONSHIP BETWEEN PRODUCT DESIGN, LEAN MANUFACTURING AND OPERATIONAL PERFORMANCE OF SUGAR FIRMS IN KENYA for the period ending : 22/June/2024.

License No: **NACOSTI/P/23/26766**

608442

Applicant Identification Number

Director General

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Verification QR Code

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See overleaf for conditions