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TECHNOLOGY

THE MODERATING ROLE OF QUALITY FUNCTION DEPLOYMENT ON ENHANCING THE EFFECT OF ADVANCED MANUFACTURING TECHNOLOGY ON PERFORMANCE OF MANUFACTURING COMPANIES IN KENYA

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ABSTRACT

Purpose of the study: The study investigated the moderating effect of quality function deployment (QFD) on the relationship between Advanced Manufacturing Technology (AMT) and Performance of manufacturing companies in Kenya.

Methodology: The study used a mixed methods research design that included exploratory factor analysis and descriptive cross-sectional survey involving 80 manufacturing companies in Kenya. Random sampling was used to identify the manufacturing companies that were members of Kenya Association of Manufacturers (KAM), from which data was collected using a self administerd questionnaire. The study used exploratory factor analysis to identify factors that influence manufacturing companies in Kenya to adopt AMT in their production process.

Findings: The study identified nine factors that influence the adoption of AMT in Kenya, including: product customization to meet customer needs, product innovation, flexibility and agility in production, product quality and consistency, cost reduction, and production efficiency improvement. Additionally, stepwise regression models were used to test the moderation hypothesis developed by the study. The results revealed that AMT statistically predicts the performance of manufacturing companies in Kenya ($R = 0.458$, $R^2 = 0.210$, $F = 15.929$, $p < 0.01$), and that QFD moderates the relationship between AMT and the performance of manufacturing companies in Kenya.

Conclusion: The study concludes that QFD moderates the relationship between AMT and the performance of manufacturing companies in Kenya, with factors like product customization, innovation, and employee training being crucial for achieving benefits such as improved product quality, increased efficiency, and cost reduction.

Recommendations: The study recommends that manufacturing companies in Kenya should identify the key AMT factors relevant to their goals before adoption and integrate QFD principles to enhance customer satisfaction, improve collaboration, and drive continuous improvement in their operations. Additionally, companies should regularly evaluate and adjust their AMT strategies in line with evolving customer demands and market conditions to sustain long-term competitive advantages.

Keywords: *Advanced Manufacturing Technology, Quality Function deployment and Performance.*

INTRODUCTION

Traditional manufacturing companies have relied on traditional manufacturing technologies over the years to improve their production efficiency, while modern manufacturing companies employ AMT in their operations to enhance their overall performance by developing and sustaining competitive advantage (Musebe, 2023; Lee, 2021; Simachey, 2021; and Pham et. al., 2020). Advanced manufacturing technology has been largely defined depending on the industry, the production process, and other factors that address cost of production, quality of products, speed of product delivery to the market, product customization and product positioning among other performance parameters (Musebe, et. al., 2020; Gunawardana, 2006).

Further, AMT has also been defined as computer-based technologies that fill the 'automation gap' between mass production and one-off ends of the manufacturing spectrum (Goyal & Grover, 2012; Kotha & Swamidass, 2000; Bessant & Haywood, 1985; Craven & Slatter, 1988; Fulton & Hon, 2009; Zammuto & O'Connor, 1992; Small & Chen, 1995; Baldwin & Diverty, 1995). This study considered AMT to include all manufacturing technologies that aid manufacturing companies to optimize their manufacturing processes, customize and align their product development process to their manufacturing capability, develop flexibility and agility in their production process to meet their customer needs, achieve cost efficiency, and offer consistently reliable products of high quality.

According to Wang et al (2023), the advent of AMT, has made it possible for manufacturing companies to meet customer needs with complicated geometry, great customizability, and specific qualities without being constrained by traditional manufacturing methods. Manufacturing companies use AMT through planning technologies, design technologies and manufacturing technologies, to meet customer needs as well as realize their deliberate and emergent manufacturing strategies as envisaged by Mintzberg et al (1985). Manufacturing companies also use AMT to transform ideas from their research and design departments coupled with feedback from their customers into products and, to meet market requirements through deliberate and emergent manufacturing strategies as proposed by Mintzberg et al (1985).

Quality Function Deplyment (QFD) is a comprehensive quality system employed by manufacturing companies to link the needs of the customer with various business functions and organizational processes to align the entire company toward achieving a common goal. Manufacturing companies use QFD as a systematic design support technique to improve the quality of manufactured products or offered services (Lim, et al., 2012; Akao, 2004). Specifically, QFD is appropriate for systematically considering the expectations and needs of customers to achieve the most important objective of the company and provide the ultimate customer satisfaction (Dikmen, Birgonul & Kiziltas, 2005). This study investigated the factors that influence manufacturing companies in Kenya to adopt AMT and the moderating effect of QFD on the relationship between AMT and performance of manufacturing companies in Kenya. Specifically, the study explored how QFD affects the relationship between factors that explain adoption of AMT and performance of manufacturing companies in Kenya.

LITERATURE REVIEW

Manufacturing companies are facing several emerging issues that affect their performance reducing their competitivenes and their ability to meet their customer needs effectively. These issues include; supply chain disruptions, workforce shortages & skill gaps, rising costs & inflation, technological disruptions, sustainability & environmental regulations, global competition & market volatility, and the ever-changing consumer preferences. In order to maintain their overall equipment efficiency, reduce defect rates, increase their throughput and labour productivity, increase their energy efficiency and maintain their profit margins, manufacturing companies adopt both AMT and QFD in their production processes.

Advanced Manufacturing Technology

Advanced Manufacturing Technology is the integration of cutting-edge technologies and innovative processes by manufacturing companies to enhance their manufacturing efficiency, quality, and flexibility (Varriale, et al., 2025; Raoufi, et.al., 2024). It represents a significant shift from traditional manufacturing methods by incorporating automation, data analytics, artificial intelligence (AI), and digital connectivity in the design of new products and the subsequent manufacturing process. Increasing demand for high-performance products, rapid production cycles, and cost-effective manufacturing, has made AMT become significant and crucial to manufacturing companies on increasing and/or maintaining market share and competitiveness in global markets. Further, Muller et. al. (2024), found that AMT has progressively transformed production processes and supply chain management, enabling greater product customization by focusing on demand forecasting and the optimization of prototyping processes.

Kotha and Swamidass (2000) also found that manufacturing companies adopt AMTs to enhance efficiency, reduce costs, and remain competitive in the global market. By employing AMT in their production processes, manufacturing companies can achieve high efficiencies, transforming inputs into desired outputs at the lowest possible cost by reducing conversion time, materials, and energy (Sukathong et al., 2021). Automation and robotics have been shown to help lower labor costs by reducing dependence on human workers while improving productivity and efficiency (Rosati et al., 2023). Furthermore, smart manufacturing technologies optimize material usage, minimize waste, and enhance energy efficiency, leading to significant cost savings. Therefore, by leveraging AMTs, companies can streamline their operations, produce high-quality products at a lower cost, and sustain their competitive advantage in their respective industries.

Another major factor driving the adoption of AMTs is the need for improved product quality and consistency. This factor is linked to competitive pressure and market demands, which have been intensified by globalization. According to Kim et al. (2018), AMT enables manufacturing companies to use real-time monitoring and quality analysis online, providing real-time production data analytics and predictive algorithms that lead to informed decision-making and high-quality products. High quality in manufacturing significantly improves performance by increasing customer satisfaction, reducing production costs due to fewer defects and rework, enhancing operational efficiency, improving brand reputation, and ultimately driving greater profitability (Bello Pintado et al., 2015). Additionally, AMT enables manufacturing companies to meet customer needs, helping them consolidate and increase their market share, thereby ensuring continued revenues and operations.

Manufacturing companies employ AMTs such as AI-driven quality control, precision machining, and automated inspection systems to ensure that products meet high standards with minimal defects (Yuan, et. al., 2022; Zeba, et. al., 2021; Tliba, et. al., 2023; Chung, 2021). Advanced manufacturing technology through AI-driven quality control provides manufacturing companies the solution of integrating quality in the production system to manage the consistency in manufacturing processes. This helps manufacturing companies to significantly reduce product defects, rework, and material waste, leading to greater customer satisfaction. Customers are now days highly informed and demand high-quality, customizable, and innovative products, pushing manufacturers to invest in flexible production technologies such as 3D printing and smart automation (Barrionuevo, et. al., 2024). These technologies enable mass customization, allowing businesses to quickly adapt to changing consumer preferences and market trends without compromising efficiency and quality.

Flexibility and agility in production have also been considered to be critical advantages offered by AMTs to manufacturing companies (Abdelilah, et. al., 2018). Agility is a strategic ability that enables a manufacturing company to establish a strategic long-term vision while flexibility is considered as an operational ability. Operational abilities lead manufacturing companies to operate and deliver results as designed, including managing processes, resources, and tasks efficiently to achieve desired outcomes although product functionality and performance remain as key considerations to the consumer. Manufacturing companies use AMT for quick changeovers, real-time monitoring, and predictive maintenance, reducing downtime and increasing operational efficiency. The other factors which have led to adoption of AMT by manufacturing companies include innovation and technological advancements, Regulatory and environmental considerations, Government policies, subsidies and incentives, Supply chain optimization, Workforce challenges and return on investment (Stornelli, et. al., 2021).

While the initial investment in AMT may be high, factors that include long-term benefits such as, cost savings, scalability, and higher productivity, often outweigh the initial AMT investment costs. Manufacturing companies that invest in AMTs expect to gain operational efficiency, enhance product quality, and secure a sustainable competitive advantage in the long run and by adopting AMTs, companies can future-proof their operations, meet evolving market demands, and drive sustainable growth in an increasingly digital and automated industrial landscape. Therefore, manufacturing companies rely on different factors of AMTs to justify their adoption in their operations. This study investigated the factors that lead manufacturing companies in Kenya to adopt AMTs using exploratory factor analysis.

Quality Function Deplyoment

Manufacturing companies employ QFD in their operations for different reasons including: gaining a better understanding of their customers; utilizing customer feedback for continuous improvement; establishing a better structure of requirements in relation to new product development and having an efficient way of allocating resources to focus on critical improvement opportunities (Agarwal & Ojha, 2023). Manufacturing companies also use QFD to translate product features and characteristics as envisaged by the customer into the final product. According to Benner et. al. (2003), manufacturing companies can use the four steps in QFD to develop new products or carry out modifications on existing products to meet customer needs while at the same time effectively competing against other products in the market. The four steps of QFD include, product planning, product design, developing manufacturing processes and developing process controls and parameters to be used by the quality function to finally deliver the required product to the market. When Manufacturing companies follow these QFD steps in their production process, they tend to reduce their design costs as they get it right the first time in delivering the required product to their customers (Homkhiew et al, 2012).

Manufacturing companies that implement Quality Function Deployment (QFD) in their production processes aim to be more customer-focused, ensuring they meet customer needs by aligning their activities with customer requirements and enhancing the overall customer experience (Radosław & Wies, 2023). QFD fosters a culture of agility, enabling companies to respond quickly to customer needs and improve satisfaction and retention. The benefits associated with QFD, such as improving teamwork, making trade-offs between customer demands and production capacity, and enhancing communication between departments, are similar to those of AMTs (Mehrjerdi, 2010). However, while QFD has been shown to positively impact performance in some companies, other studies report mixed results, with only about 25% of projects experiencing significant benefits, mainly in product development rather than manufacturing process improvements (Griffin, 1992; Cristiano et al., 2001). This study therefore investigated the moderating effect of QFD on the relationship of AMT and performance of manufacturing companies in Kenya by developing and testing the following hypothesis:

H_1: Quality function deployment moderates the relationship between AMT and performance of manufacturing companies in Kenya.

METHODOLOGY

This was a mixed methods cross-sectional study that used exploratory factor analysis, quantitative and qualitative descriptive design on manufacturing companies in Kenya that were members of Kenya Association of manufacturers (KAM) as at 31st of November 2024. To operationalize the study variables, planning technologies, design technologies and manufacturing technologies were used to operationalize AMT, QFD was operationalized using the house of quality metrics while performance was operationalized using non-financial metrics; customer satisfaction, market share and employee retention. The response rate of the study was 78.75% from a total of 80 manufacturing companies in Kenya that had been identified for the study using a random sampling technique. Data was collected using a self adminstered questionnaire. Data was analysed using exploratory factor analysis to determine factors that influence adoption of AMT by manufacturing compaanies in Kenya. Diagnostic tests were done to confirm if the data were normally distributed to allow parametric tests to be done on testing the study hypothesis. Stepwise regression models were then used to analyse the data and test the hypothesis on moderation using Kenny and Baron (1986) model. The results are presented in the next section.

RESULTS AND DISCUSSION

Introduction

Results of the study are presented using both descriptive statistics and stepwise regression model analysis on the moderating effect of QFD on the relationship between AMT and performance of manufacturing companies in Kenya.

Diagnostic Tests

Diagnostic tests that included reliability test, validity test, normality test and multi-collinearity test were done on the data before conducting parametric tests.

Reliability Test

The results as presented in Table 1 show that Cronbach (α) had a minimum value of 0.956 for performance and a maximum value of 0.972 for QFD which were within the acceptable range for the study of 0.58 and 0.97. The results show that AMT (67 items), QFD (28 items), and performance of manufacturing companies in Kenya (47 items) were each uni-directional with a Cronbach's α ranging between 0.956 and 0.972, further confirming internal consistency and reliability of the data (Tavakol & Dennick, 2011). Results are presented in Table 1.

Table 1: Reliability Test of Study Variables

Variable	Number of Cases	Number of items in Scale	Cronbach's Alpha (α)
Advanced Manufacturing Technology	63	67	0.972
Quality Function Deployment	63	28	0.956
Performance of Manufacturing Companies in Kenya	63	47	0.956
Acceptable values of Cronbach's (α) for the study are between 0.58 and 0.97			

Normality Test

From initial results on normality, the data for QFD and performance of manufacturing companies in Kenya were not normal. Since parametric analysis was to be used to determine the relationship between the variables of the study, it was neccesary to transform the data using the Box-Cox method (Atkinson, Riani & Corbellini, 2021). Both the Shapiro – Wilk test and the Kolmogorov-Smirnov Test were used to test for normality. After transforming data for QFD and performance of manufacturing companies in Kenya, results show normality and therefore allows parametric tests to be used in analysing the data. Results are presented in Table 2.

Table 2: Normal Distribution Test for the Study Variables

Variable	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Advanced Manufacturing Technology	.085	62	.200*	.970	62	.132
Quality Function Deployment*	.020	62	.200*	.996	62	.999
Performance of Large Manufacturing Companies in Kenya*	.063	62	.200*	.955	62	.023

* After Box-Cox transformation

Validity Test

The study employed the Pearson correlation coefficient method to test for validity of the research questionnaire. The results show a high significance <.005 on the correlation matrix confirming validity.

Table 3: Validity Test

		Performance	QFD	AMT	Total
Performance	Pearson Correlation	1.000			
	Sig. (2-tailed)				
	N	62			
QFD	Pearson Correlation	.777**	1.000		
	Sig. (2-tailed)	<.001			
	N	62	62		
AMT	Pearson Correlation	.593**	.734**	1.000	
	Sig. (2-tailed)	<.001	<.001		
	N	62	62	62	
Total	Pearson Correlation	.864**	.927**	.899**	1.000
	Sig. (2-tailed)	<.001	<.001	<.001	
	N	62	62	62	62

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

The results show that the study instrument was valid and could be used to collect data. The critical value for the study at 95% confidence interval and 62 degrees of freedom was 0.24 (Guide 15, 2019). The results are presented in Table 3.

Multi-Collinearity Test

Multicollinearity relates to a situation where the predictors in a study are to a high extent correlated. The test for multicollinearity was undertaken within the framework of Variance Inflation Factor and the results are presented in Table 4.

Table 4: Multicollinearity Test

Variable	Collinearity Statistics	
	Tolerance	VIF
Advanced Manufacturing Technology	0.516	1.938
Quality Function Deployment	0.516	1.938

a. Dependent Variable: Performance of Manufacturing Companies in Kenya

The threshold for the multicollinearity test was 5 and the results in Table 4 indicate that all the predictors had VIF values below 2 indicating the absence of high collinearity level among the predictor variables.

Exploratory Factor Analysis Results

Exploratory factor analysis was done to determine the factors that influence adoption of AMT by manufacturing companies in Kenya. To identify the names of factors in the three constructs that were used to operationalize AMTs in the study, the item that had the highest factor load on a factor, and contributed the most to that factor, was used as the basis (Sappaile, Abeng, & Nuridayanti, 2023). The results for all the constructs of AMT using the KMO and Bartlett's test show that Kaiser-Meyer-Olkin Measure of Sampling Adequacy is > 0.5 and they are significant. This allows for the study to proceed and interpret the results of the exploratory factor analysis. Results are presented in Table 5. The first construct of AMT on which the study carried out exploratory factor analysis was design technologies. An Eigen value > 1, with a total variance explained was used to determine the number of factors to extract. Further, the pattern matrix was used to interprete the results as the study used an oblique rotation.

Table 5: KMO and Bartlett's Test

Advanced Manufacturing Technology Construct	KMO and Bartlett's Test Results		
Design Technologies	Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.871
		Sig.	<.001
Manufacturing Technologies	Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.871
		Sig.	<.001
Planning Technologies	Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.867
		Sig.	<.001
Minimum value of Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.5			

Using exploratory factor analysis, a total of 21 items were used to determine the factors that influenced manufacturing companies in Kenya to adopt design technologies. The results show that 8 items converged around the factor, product customization to meet customer needs. The second factor identified had 6 items that converged around the factor, Product innovation. Further, 5 items converged about the factor product development and the last factor, employee training had 2 items. Arising from the findings of the study, 4 factors, Product customization to meet customer needs, Product innovation, Product development, and employee training were identified to influence adoption of design technologies by manufacturing companies in Kenya. The results of this study are similar with the finding of Henao-Ramírez et. al. (2022), Spina et. al (2002), and Khin and Kee, (2022) on factors that influence adoption of design technologies. They found that perceived usefulness and technological competence, Organizational factors, including top management support and internal consistency with existing practices, Environmental factors, such as competitive pressures and customer requirements, influence and are crucial for successful adoption of design technologies by manufacturing companies. Results are presented in Table 6.

Table 6: Factor Analysis for Design Technologies in Manufacturing Companies in Kenya

Pattern Matrix[a]

Individual Questions (Items)	Component (Factor)			
	1	2	3	4
We are interested with how our customers use our products	0.815			
We know how to use technology in our company	0.765			
Enhanced efficiency, speed, and reduced waste in production are Key Performance Indicators in our company	0.636			
Using technology in new product development enables our company to exploit the opportunities in the market faster compared to our competitors	0.612			
Our company is able to adopt new process technologies quickly	0.596			
Technology helps our company meet the needs of our customers	0.559			
We learn and understand the effect of emerging technologies on product performance	0.547			
We design our new products in response to the needs of our customers	0.529			
The company uses Computer aided design (CAD) when developing new products		0.906		
Computer Aided Design (CAD) helps our company to reduce the time taken to develop new products		0.912		
Process Engineers are involved from the early stages of product development using CAD		0.902		
Design using CAD enables our company to address special needs in the market		0.872		
Our expert knowledge in the use of CAD enables our company to stay ahead of our competitors in our industry		0.892		
CAD makes our company quickly implement changes required by customers in the market		0.826		
Product development managers have a final say in the product development process			0.882	
The production department plays a big role in the design of products since they are the ones who will produce them			0.836	
All employees involved in the new product development process are accountable to the research and development team			0.812	
Employees in our research and product development department meet with customers to understand what they want			0.791	
Process design is done concurrently with product design			0.733	
Our company has developed a policy for training employees to effectively use design technologies				0.854
Our suppliers develop the products (spares) they supply to our company				0.772

"Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization."
a. Rotation converged in 17 iterations.

The study also used exploratory factor analysis to investigate the factors that inluence manufacturing companies in Kenya to adopt manufacturing technologies in their operations. A total of 20 items were used in the current study.

Table 7: Factor Analysis for Manufacturing Technologies in Manufacturing Companies in Kenya

Pattern Matrix[a]

	Component (Factor)		
	1	2	3
Production team use technology to forecast required production volumes	0.925		
Production team use technology to develop production plans that satisfy customer demands fully	0.885		
Production team adapts production to changing customer needs	0.817		
Manufacturing technology is at the core of expanding our business to new frontiers while maintaining our current markets	0.765		
Manufacturing technology enables production consistency leading to maintaining product positioning	0.759		
Technology reduces rework incidents	0.714		
Manufacturing technologies help our company to achieve a lean manufacturing strategy	0.694		
Benefits of technology cause investments in in manufacturing technologies	0.686		
Manufacturing technologies enable production of quality products	0.674		
Data and reports from Manufacturing technologies aid decision making	0.603		
Manufacturing technologies helps in reducing unit production cost	0.516		
Our company uses Computer integrated manufacturing (CIM) for quality		0.838	
Our company uses Computer aided manufacturing (CAM) to assure quality		0.799	
We have Computer numerically controlled machines (CNC) that we use in our production process to maintain our quality consistently		0.783	
Numerically controlled machines (NC) are incorporated in our production process to achieve the high quality required by our customers		0.759	
Computer aided inspection (CAI) improve quality and reduces customer complaints related to quality		0.737	
Flexible manufacturing systems (FMS) help us to be agile and meet quality		0.671	
Our company uses Automated guided vehicles (AGV) in our warehouse			0.719
Industrial robots have increased our throughput in manufacturing quality products			0.704
Our packaging and storage rely on Automated storage and retrieval systems (AS/RS)			0.550

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 10 iterations.

Using exploratory factor analysis, a total of 20 items were used to determine the factors that influenced manufacturing companies in Kenya to adopt manufacturing technologies in their production process. The results show that 11 items converged around the factor, Flexibility and agility in production. The second factor identified had 6 items that converged around the factor, Product quality and consistency and the last factor, Supply chain and logistics optimization had 3 items. Arising from the findings of the study, 3 factors, flexibility and agility in production, product quality and consistency, and supply chain and logistics optimization were identified to influence adoption of manufacturing technologies by manufacturing companies in Kenya. Results are presented in Table 7.

The finding of this study support the finding by Sukathong et. al. (2021), Khin and Kee (2022), Susitha (2021) and Yuksel (2022) who reckon that manufacturing companies adopt AMTs influenced by various critical factors. Strategic planning is paramount, as a well-designed strategy with clear flexible objectives that significantly impact successful implementation of manufacturing strategies aligned to meeting customer needs. Specifically, Sukathong (2021) found in Sri Lanka that organizational readiness, including employee knowledge and a supportive organizational structure, plays a crucial role in facilitating adoption of manufacturing technology, with a bias towards meeting product quality. Top management's commitment and support are vital, as leadership drives the alignment of manufacturing strategies with technological advancements. Technological infrastructure, encompassing appropriate facilities and employee competencies, is essential for seamless AMT implementation. Further, external environmental factors, such as market opportunities and how to deliver the products, competition, and customer requirements, also influence the decision to adopt AMTs, as companies strive to remain competitive and responsive to market demands (Yuksel, 2022).

On planning technologies, a total of 20 items were used to determine the factors that influenced manufacturing companies in Kenya to adopt them. The results show that 12 items converged around the factor, product quality and consistency. The second factor identified had 3 items that converged around the factor, Cost reduction. Further, 5 items converged about the factor efficiency improvement. Arising from the findings 3 factors that influenced manufacturing companies in Kenya to adopt planning technologies were identified as: Product quality and consistency, Cost reduction, and efficiency improvement. Results are presented in Table 8.

Table 8: Factor Analysis for Planning Technologies for Manufacturing Companies in Kenya

Pattern Matrix[a]

	Component (Factor)		
	1	2	3
Our company uses planning technologies to minimize waste	0.890		
Planning technologies lead to efficient Production scheduling	0.865		
There is an opportunity for 'Hard talk' between different departments during the production planning process to prioritize resources to customer needs	0.827		
We use stand alone technologies for production planning	0.788		
Planning managers rely on information from the production systems to improve the production process and product quality	0.770		
Planning technologies help companies meet product delivery timelines	0.764		
Planning technologies enable delivery of required product volumes to the market	0.748		
Management information systems (MIS) is used in our company	0.662		
Planning managers are able to have an end to end view of the production system when they are planning for production	0.592		
Just in time (JIT) is used in our company to meet customer needs	0.570		
Planning technologies lead to reduced operation downtime	0.571		
Our company achieves better alignment on available capacity utilization by using planning technologies to manage production	0.508		
We use manual production planning methods in our company		0.845	
Just in time production helps our company reduce the unit costs		0.594	
Just in time (JIT) is used in our company to meet customer needs and wants Just in time helps our company to reduce the need of inventory		0.530	
Total quality management (TQM) is embraced within the planning process in our company			0.817
Our company relies on Enterprise resource planning (ERP) for effective production planning			0.812
Using total quality management reduces the level of waste in our production system			0.742
Planning technologies enable good Customer relationship management			0.706
Planning technologies lead to better inventory control			0.568

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.
a. Rotation converged in 13 iterations.

Hypothesis Testing

The study sought to establish the moderating effect of QFD on the relationship between AMT and performance of manufacturing companies in Kenya by testing the following hypothesis:

H_1: Quality function deployment moderates the relationship between AMT and performance of manufacturing companies in Kenya.

A step-wise regression model as suggested by Kenny and Baron (1986) was used to test this hypothesis. The first step was used to determine if there exists a significant relationship between AMT and performance of manufacturing companies in Kenya. Results show a positive and moderate relationship between AMT and performance of manufacturing companies in Kenya (r=0.458). Results also show that AMT explains 21% of variations in performance of manufacturing companies in Kenya (R^2 =0.21). Further, the results show a significant F-ratio at a confidence level of 95% (F=15.929, $p< .05$) which provides evidence that the regression model attained goodness of fit and was appropriate for analyzing data and the relationships in this study. Arising from these results, there was evidence the first condition for inferring moderation was satisfied and the process proceeded to the second step of testing for moderation (Kenny & Baron, 1986). Results are presented as Model 1 in Table 9.

Table 9: Model Summary of Moderation

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change
1	0.458[a]	0.210	0.197	0.481	0.210
2	0.606[b]	0.367	0.346	0.434	0.157
3	0.639[c]	0.408	0.377	0.423	0.041

a (Predictors AMT), b (Predictors AMT and QFD), c (Predictors AMT, QFD and AMT*QFD)

In the second step for testing moderation by QFD on the relationship between AMT and performance of manufacturing companies in Kenya, multiple regression was done for AMT, QFD and performance of manufacturing companies in Kenya. Results show a positive and moderate relationship between AMT, QFD and performance of manufacturing companies in Kenya (r=0.606). Results also show that AMT and QFD together explain 36.7% of variations in performance of manufacturing companies in Kenya (R^2 =0.367). The effect of adding QFD in the regression causes a 15.7% change on variance and was found to be significant (R square change =

0.157, $p<0.05$). Further, the results show a significant F-ratio at a confidence level of 95% ($F=17.114$, $p< .05$) which provides evidence that the regression model attained goodness of fit and was appropriate for analyzing data for the multiple regression, and QFD is significant in predicting performance in the presence of AMT at a confidence level of 95% ($\beta = 0.552$, $t = 3.83$, $p< 0.05$). There is evidence from these results that the second condition for inferring that QFD moderates the relationship between AMT and performance of manufacturing companies in Kenya. The process therefore proceeded to the third step of testing for moderation. Results are presented as Model 2 in Table 10

Table 10: ANOVA of Moderation

Model		Sum of Squares	df	Mean square	f	Sig.
1	Regression	3.687	1	3.687	15.929	<.001[a]
	Residual	13.888	60	0.231		
	Total	17.575	61			
2	Regression	6.453	2	3.226	17.114	<.001[b]
	Residual	11.122	59	0.189		
	Total	17.575	61			
3	Regression	7.169	3	2.390	13.318	<.001[c]
	Residual	10.406	58	0.179		
	Total	17.575	61			

In the third step of the stepwise regression according to Kenny and Baron (1986), the interaction term (AMT*QFD) was introduced. Performance of manufacturing companies in Kenya was then regressed on the three predictors. The results show a strong and positive relation among the variables AMT, QFD, AMT*QFD and Performance of manufacturing companies in Kenya ($R = 0.639$). Introducing the interaction factor causes a 4.1% change on R^2 and is still significant (R Square change=0.041, $p<0.05$). The results also show that AMT, QFD and the interaction term AMT*QFD explained 40.8% of variations in performance of manufacturing companies in Kenya. The F-ratio is also significant ($F=13.318$, $p<0.05$) confirming suitability of the regression model justifying the use of multiple regression model for investigating the relationship between the four variables. The results show the interaction term AMT*QFD is significant at a confidence level of 95%, confirming that QFD moderates the relationship between AMT and performance of manufacturing companies in Kenya. Arising from these results we fail to reject H_1 and conclude that QFD moderates the relationship between AMT and performance of manufacturing companies in Kenya. Results are presented as model 3 in Table 11.

Table 11: Coefficients for Moderation

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.138	0.301		10.436	0.000
	AMT	0.314	0.079	0.458	3.991	0.000
2	(Constant)	2.327	0.344		6.759	0.000
	AMT	0.051	0.099	0.074	0.512	0.610
	QFD	0.450	0.118	0.552	3.830	0.000
3	(Constant)	4.640	1.206		3.848	0.000
	AMT	-0.656	0.367	-0.958	-1.790	0.079
	QFD	-0.129	0.312	-0.158	-0.414	0.680
	MODERATOR (AMT*QFD)	0.173	0.087	1.622	1.998	0.050

Discussion of Results

Arising from the exploratory factor analysis results, four factors were identified to influence adoption of design technologies by manufacturing companies in Kenya. These factors included Product customization to meet customer needs, Innovation, Product development, and Training. Design technologies, such as computer-aided design (CAD) and additive manufacturing, enable rapid prototyping and iterative development, allowing businesses to tailor products to individual customer preferences efficiently (Berman, 2012). Customizing products enable manufacturing companies in Kenya to enhance customer satisfaction, gain a competitive advantage, and increase their profitability. Product customization, according to Pine (1993), allows manufacturing companies to meet specific customer needs, leading to higher brand loyalty and repeat purchases. According to Gilmore and Pine (1997), it also differentiates companies from competitors, enabling premium pricing and reducing the risk of market commoditization, while advancements in digital manufacturing minimize the cost implications of customization (Tseng & Jiao, 2001).

Mass customization is enhanced through digital twin technology, which simulates real-world performance and facilitates personalized adjustments before production (Tao et al., 2018). When manufacturing companies in Kenya simulate real world performance, they reduce product re-work that would allow them to align the products to the taste and wants of customesr, leading to reduced product innovation costs. Furthermore, artificial intelligence-driven design tools streamline decision-making by analyzing customer data to generate optimized, user-specific product configurations (Wang et al., 2016). Training on design technologies enhances employee proficiency, leading to improved innovation, efficiency, and product quality. Uzumeri (1997), highlights the significant influence of design technologies and targeted training programs on employee performance and innovation. Well-trained teams adapt faster to new tools like CAD and AI-driven design systems, reducing errors and accelerating product development cycles (Zorriassatine et al., 2003).

Further, exploratory factor analysis results from this study identified three factors that influence manufacturing companies to adopt manufacturing technologies to include, Flexibility and agility in production, Product quality and consistency, and Supply chain and logistics optimization. Advancements in manufacturing technologies have significantly influenced various aspects of industrial operations, notably enhancing flexibility and agility, product quality and consistency, as well as supply chain and logistics optimization. The integration of Industry 4.0 technologies, including autonomous mobile robots (AMRs) and smart intralogistics, has markedly improved manufacturing flexibility and productivity. A study by Ivanov et al. (2022) demonstrated that deploying AMRs in production networks facilitates dynamic routing and real-time decision-making, enabling manufacturers to swiftly adapt to changing demands and reduce lead times. This adaptability is crucial for maintaining competitiveness in volatile markets.

The adoption of manufacturing technologies such as the Internet of Things (IoT) and data analytics has enhanced product quality and consistency. Ucar et al. (2024) highlighted the importance of IoT-enabled predictive maintenance and real-time quality monitoring systems on enabling manufacturing companies achieve early detection of equipment anomalies and product defects, minimizing downtime and ensuring uniform product standards. This proactive approach leads to higher customer satisfaction and reduced warranty claims. Manufacturing technologies have also revolutionized supply chain and logistics operations. The integration of manufacturing technologies in lean manufacturing facilitates real-time tracking of inventory and shipments, optimizing supply chain visibility and responsiveness. Koufteros et al. (2024) discussed how manufacturing technologies applications in lean manufacturing enable real-time supply chain optimization, enhancing efficiency and reducing waste. Furthermore, the emergence of Industry 5.0 emphasizes human-centric automation and collaborative robots, leading to more resilient and adaptable supply chains. Nazarian and Khan (2024) explored the impact of Industry 5.0 on supply chain performance, noting improvements in customization capabilities and operational efficiency.

The study also used exploratory factor analysis to investigate the factors that lead manufacturing companies in Kenya to adopt planning technologies. The results ffrom the study identify three notable factors; Product quality and consistency, Cost reduction, and efficiency improvement. Advanced planning technologies significantly influence product quality, cost reduction, and efficiency improvement in manufacturing. Ucar et. al. (2024) found that when manufacturing companies implement concurrent engineering practices they facilitate simultaneous development of various product aspects, leading to enhanced product quality and consistency by minimizing design errors and reducing time-to-market. Predictive engineering analytics, which integrates simulation tools and data analytics, enables early detection of potential issues, thereby reducing costs associated with late-stage design changes and improving overall efficiency. Furthermore, the adoption of artificial intelligence (AI) in research and development accelerates innovation processes, optimizes resource allocation, and enhances product personalization, collectively contributing to cost reduction and operational efficiency.

The study tested the hypothesis (**H_1)** that QFD moderates the relationship between AMT and performance of manufacturing companies in Kenya. Arising from the results in Table 11, the interaction term (QFD*AMT) was found to be significant at a 95% confidence level, confirming moderation and therefore the study fails to reject **H_1**. This finding supports the study by Hausing and Clausing (1988) who found that performance of companies improved when they employed QFD in their operations. Quality function deployment ideally represents a set of planning and communication routines, focusing and coordinating skills within an organization, first to design, then to manufacture and market goods that customers want to purchase and will continue to purchase.

Quality function deployment is operationalized in manufacturing companies using the house of quality which is the belief that products should be designed to reflect customers' desires and tastes. This requires a cross functional team that includes marketing, design engineers, and manufacturing staff working together from product conceptualization to the product being delivered to the customer (Garvin, 1987). Manufacturing companies that utilize QFD are able to reduce their new product development programs by harnessing the synergies of teams when working together coupled with listening to the customer through the voice of the customer initiatives embraced by QFD.

Quality Function Deployment and AMT are pivotal in enhancing the performance of manufacturing companies. Quality function deployment systematically translates customer requirements into engineering characteristics, ensuring that product designs align closely with market needs. This alignment leads to improved product quality and customer satisfaction. When integrated with AMTs—such as computer-aided design (CAD), computer-aided manufacturing (CAM), and flexible manufacturing systems (FMS)—the efficiency and effectiveness of this translation process are significantly enhanced. Advanced manufacturing technologie's facilitate precise and flexible manufacturing processes, enabling rapid adaptation to design changes and efficient production runs (Singhry, Abd Rahman, & Imm, 2016).

The synergy between QFD and AMTs, as presented through the results of this study, is similar to the finding of a study involving 301 manufacturing firms in Argentina and Uruguay, which found that the combination of QFD practices and AMT adoption leads to substantial improvements in manufacturing performance (Bello Pintado, Kaufmann, & Merino Diaz-de-Cerio, 2015). Specifically, manufacturing companies implementing both strategies reported enhancements across various performance metrics, including product quality, operational efficiency, and responsiveness to market demands (Bello Pintado, et. al, 2015).

The findings from this study helps to explain the benefits manufacturing companies expect when they implement concurrent engineering, a practice that emphasizes simultaneous development of product design and manufacturing processes. By fostering collaboration among cross-functional teams, concurrent engineering reduces product development cycles and accelerates time-to-market. When supported by AMTs, concurrent engineering becomes more effective, leading to streamlined operations and cost reductions. A study by Singhry, Abd Rahman, and Imm, (2016), found that the integration of AMTs with concurrent engineering practices positively influences manufacturing performance, particularly in supply chain management and production efficiency. This finding is similar to the finding in this study that QFD moderates the relationship between AMT and performance of manufacturing companies in Kenya.

CONCLUSIONS

The study concludes that Quality Function Deployment (QFD) plays a crucial role in moderating the relationship between Advanced Manufacturing Technologies (AMT) and the performance of manufacturing companies in Kenya. By incorporating the principles of QFD, such as customer focus, cross-functional collaboration, prioritization of customer needs, and continuous improvement, companies can significantly enhance their operational performance. The study also identified key factors influencing the adoption of AMT, including product customization, innovation, employee training, flexibility in production, product quality, cost reduction, and supply chain optimization. These factors are vital for manufacturing companies to gain and maintain a competitive edge in the market. Furthermore, the study emphasizes that when companies effectively align their chosen AMTs with these critical factors, they are more likely to achieve substantial benefits such as improved product quality, increased efficiency, cost reduction, and the ability to customize products to meet customer demands.

RECOMMENDATIONS

The study recommends that manufacturing companies in Kenya should identify the critical factors of AMT that are most relevant to their operations and strategic objectives before adopting AMT. By doing so, companies can ensure that the AMTs they select align with their business goals and contribute to their competitive advantage. Specifically, companies should focus on factors like product customization, flexibility, and cost efficiency, which are essential for gaining a strong market position. Additionally, the study recommends that manufacturing companies should integrate QFD principles into their operations when adopting AMT. This integration will help companies better meet customer needs, enhance collaboration across teams, and improve product quality. By applying QFD, companies can streamline their manufacturing processes, improve communication between departments, and drive continuous improvement, ultimately leading to higher levels of performance and customer satisfaction.

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