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The Effect of Deployment of Advanced Manufacturing Technology on Performance: Evidence from Large Manufacturing Firms in Kenya

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Abstract

Global manufacturing is increasingly competitive and technology-driven, prompting firms to adopt Advanced Manufacturing Technology (AMT) to sustain performance. However, empirical evidence from emerging economies—especially sub-Saharan Africa—remains scarce. This study examines the effect of AMT deployment on the performance of large manufacturing companies (>100 employees) in Kenya via a descriptive cross-sectional survey. Primary data, collected through structured questionnaires from 125 firms, were analyzed using simple linear regression. Results indicate a statistically significant, moderately strong positive relationship between AMT deployment and organizational performance ($F=19.62$, $p<0.05$; $r=0.565$), with AMT explaining 31.9% of performance variation ($r^2=0.319$). This suggests that while AMT is an important factor in the relationship between AMT and performance of large manufacturing firms in Kenya, other organizational and external factors account for the majority of the observed variance in performance. Strategic AMT investment, coupled with effective implementation and complementary organizational capabilities, is vital for maximizing benefits. These recommendations are valuable for managers, policymakers, and researchers aiming to leverage AMT for industrial performance in emerging markets.

Keywords: Advanced Manufacturing Technology, Organizational Performance, Emerging Markets, Large Manufacturing Companies, Kenya.

Introduction

The global manufacturing sector is undergoing rapid transformation, driven by digital innovations and the integration of technologies such as computer-aided design (CAD), computer-aided manufacturing (CAM), robotics, and flexible manufacturing systems (FMS) into production processes (Stornelli et al., 2021; Wong & Ngai, 2023). Research in developed economies demonstrates that AMT adoption enhances operational efficiency, product quality, and market responsiveness (Kaynak, 2018; Chen et al., 2024). However, in emerging markets—particularly sub-Saharan Africa—AMT penetration remains low, hindered by financial constraints, infrastructure gaps, and skill shortages (Fofana et al., 2021; Musebe et al., 2020).

Kenya's manufacturing sector, central to the government's "Big Four Agenda" and Vision 2030, aims to increase its GDP contribution from 9.2% to 20% (Kenya Association of Manufacturers [KAM], 2024). Yet, high production costs, limited access to finance, and technological obsolescence persist as barriers (KAM, 2022). While recent studies highlight AMT's potential benefits in Kenyan SMEs (Musebe, 2024; Achieng, 2023), empirical evidence on large manufacturers—key to employment, exports, and technology diffusion—is lacking.

This study addresses that gap by investigating the relationship between AMT deployment and performance in Kenya's large manufacturing firms, providing timely insights for digital transformation in resource-constrained contexts.

The global manufacturing landscape is undergoing a significant transformation, driven by rapid technological advancements and the integration of digital innovations into production processes (Stornelli et al., 2021). Advanced Manufacturing Technology has emerged as a pivotal factor in enhancing operational efficiency, product quality, and overall organizational performance (Singh, & Gurtu, 2022; Achieng, 2021; Pozzi et al., 2021). Some of the technologies encompassed by AMT include computer-aided design (CAD), computer-aided manufacturing (CAM), robotics, and flexible manufacturing systems (FMS), which collectively enable manufacturing companies to respond swiftly to market demands and maintain competitiveness (Wong & Ngai, 2023).

In developed economies, adoption and deployment of AMT in the production process has been extensively studied, with findings consistently indicating positive impacts on productivity and organization performance (Kaynak, 2018; Bourke, & Roper, 2016; Koc & Bozdag, 2009; Altuntas et al., 2007). A study by Swink and Nair (2007) highlighted that manufacturing companies leveraging AMT experienced significant improvements in operational metrics and market responsiveness. However, the narrative in emerging economies, particularly in sub-Saharan Africa, presents a contrasting picture. The adoption rate of AMT in these regions remains relatively low, attributed to factors such as limited financial resources, inadequate infrastructure, and a shortage of skilled labor (Musebe et al., 2020).

Kenya, as a leading economy in East Africa, has recognized the strategic importance of manufacturing in its economic development agenda. The Kenyan government's "Big Four Agenda" of 2017, underscored manufacturing as a key pillar for economic growth, and aimed to increase its contribution to the Gross Domestic Product (GDP) from 9.2% to 20% by 2022 (Kenya Association of Manufacturers [KAM], 2024). Despite these ambitions, the manufacturing sector in Kenya faces several challenges, including high production costs, limited access to finance, and technological obsolescence, which hinder its global competitiveness (KAM, 2022). These challenges affect the desired Kenyan national goal in her Vision 2030, to become a middle-income country with a manufacturing sector that contributes over 15% to GDP.

Recent studies focusing on the Kenyan manufacturing sector have begun to show the potential benefits of AMT adoption. Musebe (2023) conducted a study examining the synergy between AMT, competitive advantage, and organizational resources, concluding that manufacturing companies integrating AMT into their operations experienced enhanced performance outcomes. Similarly, research by Achieng (2023) emphasized the role of Quality Function Deployment (QFD) in moderating the relationship between AMT and firm performance, suggesting that strategic alignment and customer-focused approaches amplify the benefits of technological investments.

However, a significant gap persists in the literature concerning the empirical assessment of AMT's effect on large manufacturing companies in Kenya. Most existing studies have predominantly focused on small and medium-sized enterprises (SMEs), leaving a void in understanding how larger entities, which often have more resources and complex operations, integrate and benefit from AMT. Addressing this gap is crucial, as large manufacturing companies play a vital role in employment generation, export earnings, and technological diffusion within the economy (United Nations Industrial Development Organization [UNIDO], 2016; Baya, 2023). The dynamic nature of global manufacturing necessitates continuous

evaluation of technological adoption, deployment, and its implications on performance (Mahboob et al., 2024). A study by Deloitte (2025), observed that COVID-19 pandemic, accelerated digital transformation of manufacturing processes, compelling manufacturing companies to adopt technologies that enhance resilience and adaptability. In this context, understanding how Kenyan manufacturing companies are navigating these changes through AMT adoption becomes imperative.

This study aimed to explore the effect of AMT on performance of large manufacturing companies in Kenya by employing a descriptive cross-sectional survey design. The research sought to provide empirical evidence on the relationship between AMT deployment and organizational performance metrics such as productivity, quality, and market competitiveness.

Literature Review

Advanced Manufacturing Technology refers to the integration of innovative technologies into manufacturing processes to enhance efficiency, flexibility, and competitiveness. These technologies encompass computer-aided design (CAD), computer-aided manufacturing (CAM), robotics, and additive manufacturing among others. The adoption of AMT has been pivotal in transforming manufacturing operations, leading to improved product quality, reduced production costs, and enhanced responsiveness to market demands (Mirmahdi, & Wan Khairuzzaman, 2012). In the context of Kenya's manufacturing sector, understanding the effect of deploying AMT on organizational performance is crucial for fostering industrial growth and competitiveness.

Advanced Manufacturing Technology

Advanced Manufacturing Technology refers to the use of modern, computer-based, and automated systems in the production process. These technologies include robotics, computer-aided design (CAD), computer-aided manufacturing (CAM), flexible manufacturing systems (FMS), and more recent innovations like additive manufacturing (3D printing) and digital twin systems (Ikubanni et.al., 2022; Huang et al., 2021). Artificial Intelligence (AI)-powered digital twin systems technology is expected to adapt the traditional model-based approaches to the evolving boundary conditions and provide a demand-oriented, real-time capable evaluation basis to efficiently support decision making in multi-objective problems. The goal of AMT is to enhance efficiency, improve product quality, and reduce production costs through automation, real-time monitoring, and intelligent decision-making systems.

Globally, the manufacturing sector has adopted AMT to remain competitive in dynamic markets. In developed economies, the use of AMT has contributed to improvements in flexibility, precision, and customization in production. A study by Prester et al. (2018) found that AMT significantly improves operational efficiency and reduces waste, leading to higher profitability and customer satisfaction. Similarly, Chen et al. (2024) emphasized that AMT technologies, especially those that enable in-situ monitoring, can detect production issues in real time and automatically make corrections, thereby improve product quality, reduce product defects and also reduce time to market. The development of digital twin technology demonstrates the transformative potential of AMT (Chen et al., 2023). A digital twin is a virtual AMT model of a manufacturing system that replicates real-time processes using sensor data. This technology allows companies to simulate production outcomes, test changes before implementation, and optimize manufacturing systems without costly trial-and-error methods.

In Africa, the adoption of AMT has been slow. Fofanae et al. (2021) observed that flexible manufacturing systems are still underused in many African countries, including Kenya, due to

factors such as high implementation costs, limited technical skills, and inadequate infrastructure. Despite these barriers, awareness of the value of AMT is growing in Kenya's manufacturing sector. Concepts of identifying AMT within manufacturing process differ greatly across manufacturing companies. Gunawardana (2006) and Iztok et al. (2020) posit that AMT can be identified by using either the classical continuum or level of integration of technology in the production process. The classical continuum covers the whole manufacturing process while the level of integration is concerned with the extent of automation in each of the production processes within the whole manufacturing process.

To maintain product competitiveness, manufacturing companies either design and develop new products or introduce changes on their current products to meet user requirements. The introduction of Artificial Intelligence (AI) in design technologies, has enabled manufacturing companies to address a crucial aspect of product management that plays a pivotal role in creating successful and innovative products (Bouschery et al., 2023). Product design is a multifaceted discipline that involves creating and optimizing products to meet the needs and desires of customers. It encompasses a wide range of activities, from conceptualizing a product idea to designing its features, aesthetics, and user experience. Advanced manufacturing technology allows manufacturing companies to effectively manage the product development process, ensuring that the final product not only functions well but also appeal to the target audience (Bloom et al., 2020; Brynjolfsson et al., 2019).

Globalization has increased challenges for new product development. Design support methodologies, tools, and manufacturing systems continue to play an increasingly important role in coping with the challenges and complexities of NPD, fulfilling dynamic end-user expectations, and achieving or maintaining robust competitiveness. Integration of general digital technologies in design processes is continuously opening new prospects in design support, while dedicated advanced design technologies (ADTs) can enhance creativity, efficiency and productivity of designers (Bouschery et al., 2023). Advanced design support technologies assume a fair understanding of the way of working and the needs for tools of product designers, as well as the relationships between industrial product design processes and the use of ADTs. By managing the huge increase in the complexity of design information and tasks, and supporting the discovery of new methods of design practice, ADTs amplify human effort and reduce product costs, increase product quality and reduce time to market enabling manufacturing companies to be competitive (Stolterman, 2008).

Musebe (2024) conducted a study among Kenyan SMEs and found that AMT adoption had a positive impact on operational efficiency and customer satisfaction. The study highlighted that, technologies used in planning and design had a stronger influence on performance than those used only for manufacturing, suggesting the strategic importance of aligning AMT with organizational goals. However, successful adoption of AMT requires more than just investment in production equipment. Organizational readiness, including employee skills, leadership commitment, and integration of technology into the company's overall strategy, is essential. Manufacturing companies that have not embraced these factors may struggle to realize the full benefits of AMT. Prester et al. (2018) stress that AMT alone does not guarantee improved performance, it must be supported by changes in work processes and human resource capabilities.

Organizational Performance

Manufacturing companies determine their performance using either financial indicators or non-financial indicators. These indicators include productivity, profitability, product quality, and responsiveness to market changes among others. Studies have shown that manufacturing

companies that employ AMT in their operations often report improvements in delivery times, reduced costs, and better product customization, all of which contribute to customer satisfaction and competitive advantage (Dongming, 2024; Achieng, 2021; Kotha & Swamidass, 2000; Small, 1999; Wall, et al.,1999).

Mboga, Datche, and Kising'u (2023) found that product, process, and marketing innovation capabilities were positively related to performance in manufacturing companies in Nairobi, Kenya. Their findings support the view that technological innovation, such as AMT, plays a vital role in enhancing manufacturing company competitiveness and sustainability. Mboga, et al. (2023) emphasized that organizations that invest in both technological and human capabilities are more likely to succeed. Therefore, besides investing in AMT, manufacturing companies should consider other key success factors in their industry to realize the full benefits of employing AMT in their production process.

This study builds on these findings by specifically exploring the relationship between AMT deployment in the production process and performance in large manufacturing companies in Kenya. By focusing on large manufacturing companies in Kenya, which generally have more resources and influence, the research aims to provide insights into how AMT contributes to organizational success and what conditions are necessary for its effective use. The study developed the following hypothesis to investigate the effect of deployment of AMT on performance of large manufacturing companies in Kenya:

H_1: There is a significant relationship between deployment of AMT and performance of large manufacturing companies in Kenya.

Methodology

This study adopted a descriptive cross-sectional survey design to examine the effect of deployment of AMT on performance of large manufacturing companies in Kenya. This design enabled the collection and analysis of quantitative data at a single point in time, suitable for assessing relationships between variables without manipulating the study environment. The target population comprised large manufacturing companies in Kenya with more than 100 employees and that were members of Kenya Association of Manufacturers (KAM). This threshold ensured the inclusion of companies with adequate resources and operational scale to implement AMT. This was a census study owing to the number of large manufacturing companies that are members of KAM.

Primary data were collected using a structured questionnaire developed based on established literature on AMT and firm performance. The instrument consisted of three sections: (i) demographic characteristics; (ii) extent and type of AMT deployed and (iii) performance metrics that included customer satisfaction and employee retention. A five-point Likert scale was used to quantify responses related to AMT deployment and performance perceptions. Data were analyzed using SPSS. Pearson correlation analysis assessed the strength and direction of the relationship between deployment of AMT and performance of large manufacturing companies in Kenya(R). Simple linear regression analysis was conducted to determine the explanatory power for deployment of AMT on performance of large manufacturing companies' outcomes. The model's significance was tested using the F-statistic, with an alpha level of 0.05, while the coefficient of determination (R^2) was used to indicate the proportion of variance in performance of large manufacturing companies in Kenya explained by deployment of AMT. To ensure content validity, the questionnaire was reviewed by subject matter experts in manufacturing and industrial engineering. A pilot test involving five manufacturing firms was

conducted to refine the instrument. Internal consistency and reliability, was assessed using Cronbach's alpha.

Participation was voluntary, and informed consent was secured prior to data collection. Respondents were assured of the confidentiality and anonymity of their responses, and all data were used solely for academic purposes. The results are presented in the next section.

Results

Reliability Test

Using Cronbach (α), the results (α=0.9) confirm data for the study achieved the desired reliability and internal consistency from the items in the questionnaire as advocated by Murphy and Davidshofer (2001), to be used in determining the relationship between deployment of AMT and performance of large manufacturing companies in Kenya. The results are presented in Table 1

Table 1: Reliability Test

Variable	Cronbach's Alpha (α)	Number of items in Scale
Deployment of Advanced Manufacturing Technology	0.9	22
Organizational Performance	0.9	14

Acceptable values of α for the study were between 0.58 and 0.97

Normality Test

Normality test was done on the dimensions for deployment of AMT, design technologies; manufacturing technologies; and planning technologies; as well as for the dimensions of performance of large manufacturing companies in Kenya, customer satisfaction and employee retention. The results for normality using the Shakiro-Wilk test show that all the study variable dimensions were normally distributed ($p>0.05$). This allowed the study to conduct parametric statistical tests to determine the relationships between the variables in the study. Results are presented in Table 2.

Table 2: Normality Test for the Variable Dimensions

Study Variable	Dimension	Skewness		Scale Kurtosis		Shapiro-Wilks	
		Statistic	Std. Error	Statistic	Std Error	Statistic	Sig.
Deployment of Advanced Manufacturing Technology	Design Technologies	-0.024	0.369	-1.109	0.724	0.933	0.058
	Planning Technologies	-0.242	0.369	-0.556	0.724	0.976	0.520
	Manufacturing Technologies	-1.179	0.369	0.452	0.724	0.844	0.100
Performance of Large Manufacturing Companies in Kenya	Customer Satisfaction	-0.306	0.369	-0.579	0.724	0.939	0.068
	Employee Retention	-0.873	0.369	1.942	0.724	0.904	0.502

p>0.05 and Statistic ≈ 1 for normality using the S-W test

Multi-Collinearity Test

The test for multicollinearity was undertaken within the framework of Variance Inflation Factor (VIF) and the results are presented in Table 3. The threshold for the multicollinearity test was a VIF value of 5 and the results in Table 3 indicate that deployment of AMT had a VIF value below 2 indicating the absence of high collinearity level between deployment of AMT and performance of large manufacturing companies in Kenya.

Table 3: Multicollinearity Test

Variable	Collinearity Statistics	
	Tolerance	VIF
Deployment of Advanced Manufacturing Technology	0.653	1.531

a. Dependent Variable: Organizational Performance in Large manufacturing Companies in Kenya

Hypothesis Testing

The purpose of this study was to examine the effect of deployment of AMT on the performance of large manufacturing companies in Kenya by testing the following hypothesis:

H_1: There is a significant relationship between deployment of AMT and performance of large manufacturing companies in Kenya

The regression analysis results revealed a positive and statistically significant relationship between AMT deployment and company performance.

The results indicate a moderate positive relationship between deployment of AMT and performance of large manufacturing companies in Kenya (R=0.565). The results also indicate that approximately 31.9% of the variations observed in performance of large manufacturing companies in Kenya, can be explained by the level of AMT deployment (R^2 = 0.319). The

adjusted R^2, was slightly lower at 0.303, suggesting the model has a good fit while remaining generalizable. Results are presented in Table 4.

Table 4: Regression Model Summary

Model Summary			
R	R Square	Adjusted R Square	Std. Error of the Estimate
.565[a]	0.319	0.303	0.43722
a. Dependent Variable: Performance of Large Manufacturing Companies in Kenya			

Results presented in Table 5. confirmed the overall statistical significance of the regression model, with an F-value of 19.662 and a p-value of 0.000 ($F=19.662$; $p<0.05$). This finding shows that the model significantly predicts the performance of large manufacturing companies in Kenya based on the level of AMT deployment. Further, the results indicate a significant relationship between deployment of AMT and performance of large manufacturing companies in Kenya. Results are presented in Table 5.

Table 5: ANOVA Results

	Sum of Squares	**Df**	**Mean Square**	**F**	**Sig.**
Regression	3.759	1	3.759	19.662	.000[b]
Residual	8.029	42	0.191		
Total	11.787	43			
b. Predictors: (Constant), Deployment of Advanced **Manufacturing Technology**					

Looking at the results in table 6 for coefficients, the regression equation had a constant value of 3.142. This implies that when there is no deployment of AMT, the expected baseline score of large manufacturing companies in Kenya is 3.142. The unstandardized coefficient for AMT deployment was 0.318, indicating that for every one-unit increase in the deployment of AMT, performance of large manufacturing companies in Kenya increases by 0.318 units. This relationship is statistically significant, as evidenced by a t-value of 4.434 and a p-value of 0.000 ($\beta=.318$, $t = 4.434$, $p< .05$). Furthermore, the standardized beta coefficient was 0.565, which further suggests that AMT deployment has a moderately strong influence on performance of large manufacturing companies in Kenya. Results are presented in Table 6.

Table 6: Regression Coefficients Results

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	3.142	0.23		13.677	0.000
Deployment of Advanced Manufacturing Technology	0.318	0.072	0.565	4.434	0.000

Discussion

The results of this study indicate that the deployment of Advanced Manufacturing Technology (AMT) significantly and positively influences the performance of large manufacturing companies in Kenya. The regression analysis revealed a correlation coefficient (R) of 0.565, suggesting a moderately strong positive relationship between AMT deployment and performance of large manufacturing companies in Kenya. The coefficient of determination (R^2 = 0.319) implies that approximately 31.9% of the variation in performance of large manufacturing companies in Kenya can be explained by deployment of AMT. The regression coefficient (β = 0.318, t = 4.434, F = 19.662, $p < .05$) confirms that this relationship is statistically significant.

These findings support the broader consensus in the literature that AMT enhances organizational flexibility, efficiency, and responsiveness to changing market conditions, all of which contribute to improved performance (Kotha & Swamidass, 2000). Deployment of AMT in the manufacturing process facilitates both operational and strategic gains, enabling manufacturing companies to adopt manufacturing strategies that focus on cost leadership, differentiation, or a hybrid of both. This technological capability allows manufacturing companies to adjust their production systems rapidly, improving their adaptive and tactical performance outcomes.

Previous studies also underscore the importance of aligning AMT with organizational strategies and supplier relationships to ensure successful implementation and deployment within the manufacturing process. For instance, Rahman et al. (2008) emphasized the critical role of collaborative relationships with AMT suppliers during the implementation phase to ease deployment challenges often faced by manufacturing companies. Effective supplier engagement not only facilitates the transfer of technical know-how but also enhances customization and ongoing support, which, in turn, improves the performance of manufacturing companies.

The findings further suggest that deploying AMT in the manufacturing process supports lean manufacturing principles, including waste reduction, process simplification, and quality enhancement. Swink and Nair (2007) found that the performance benefits of deploying AMT are amplified when it is complemented by design technologies and lean practices, enabling manufacturing companies to achieve higher quality and delivery performance. In the context of Kenyan manufacturing companies, these technologies appear to enable faster production cycles, improved resource utilization, and better responsiveness to customer needs.

Additionally, deploying AMT in the manufacturing process contributes to sustainability and competitive advantage. Shokrani and Biermann (2020) highlighted that deploying AMT in the manufacturing process enhances the sustainability of manufacturing operations by improving tool life, reducing material waste, and enhancing product quality. These benefits are particularly relevant in global markets where environmental and quality standards are increasingly stringent. Similarly, García-Sánchez, García-Morales, and Martín-Rojas (2018) emphasized that deploying AMT supports strategic positioning by enabling faster innovation cycles and reducing research and development (R&D), and distribution costs. This capability allows manufacturing companies to remain competitive while catering to dynamic customer preferences.

Despite these benefits, the study also reveals that 68.1% of the variation in performance of large manufacturing companies in Kenya is influenced by other variables. This finding aligns with the view of Musebe et al. (2020), who caution that AMT alone is not a panacea for performance improvement. Factors such as human resource capacity, change management, leadership commitment, and strategic alignment are equally critical in realizing the full potential of AMT investments. Manufacturing companies that focus solely on technology deployment without integrating it into a broader strategic and organizational context may not achieve the desired outcomes. Further, Boyer et al. (1997) reckon that successful AMT implementation requires more than technological investment; it demands organizational readiness, alignment with strategic objectives, and effective integration with human and structural capital. Future research could explore these complementary factors and assess their moderating effects on the relationship between AMT and performance across various industrial sectors.

Conclusion and Recommendations

This study examined how deployment of AMT affects the performance of large manufacturing companies in Kenya. The results showed that there is a clear and moderately strong positive relationship between using AMT and improved company performance. This study concludes that, manufacturing companies that choose the right technologies and implement them well will experience better performance. However, just having and deploying AMT in the manufacturing process is not enough to improve performance, but companies also need to invest in other areas like staff training and proper planning to gain full benefits.

Many manufacturers face challenges in adopting AMT. The high cost of machines, poor infrastructure such as unstable electricity and slow internet, and a shortage of skilled workers make it difficult for companies to use AMT effectively. Some employees also resist these changes due to fear of job loss or discomfort with new systems. To overcome these issues, companies should plan their AMT use carefully, train their staff, invest in better infrastructure, and create a culture that supports innovation and learning. The government should also play an important role by offering incentives, improving infrastructure, and supporting technical education. If these steps are taken, AMT can help Kenyan manufacturers improve quality, boost productivity, and compete better in the market.

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