

ARTIFICIAL INTELLIGENCE ROBOTS AND SUPPLY CHAIN EFFECTIVENESS OF FOOD AND BEVERAGES MANUFACTURING FIRMS IN NIGERIA

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Abstract

This study investigated the relationship between artificial intelligence (AI) robots and supply chain effectiveness of food and beverages manufacturing firms in Nigeria. AI robots is the predictor variable, and supply chain effectiveness (measured as delivery performance, logistics cost, and asset management) is the criterion variable. The study aligned with the positivist philosophy, hence, favoured a quantitative methodology and a survey research design. The population of the study comprised 17 quoted food and beverages manufacturing firms in Nigeria; and all were surveyed. A total of 77 respondents from the food and beverages manufacturing firms provided valid data for the study through a 16 item questionnaire. Pearson Product Moment Correlation (PPMC) was used to test three null hypotheses with the aid of Statistical Package for Social Sciences (SPSS) version 22.0. The study found that AI robots have positive significant relationship with delivery performance, logistics cost and asset management of food and beverages manufacturing firms in Nigeria. Thus, the study concluded that AI robots have positive and significant relationship with supply chain effectiveness of food and beverages manufacturing firms in Nigeria; and recommends that food and beverages manufacturing firms in Nigeria should invest in AI robots to enhance delivery performance, logistics cost savings, and asset management.

Keywords: Artificial intelligence robots, asset management, supply chain effectiveness, delivery performance, logistics cost

Introduction

In recent years, the deployment of Artificial Intelligence (AI) robots in supply chain management has become increasingly essential, particularly for food and beverage firms. With the Nigerian economy heavily dependent on agriculture and manufacturing, effective implementation of AI technology in supply chain processes addresses numerous operational challenges (Adeleke et al., 2023); including poor infrastructure, logistics inefficiencies and frequent supply-demand fluctuations. As food and beverage manufacturers grapple with the need for enhanced accuracy, speed, and flexibility in production and distribution, AI-powered robots present an opportunity to bridge gaps and optimize the entire supply chain (Eke et al., 2023).

AI robots possess the ability to analyze vast datasets, predict market trends and automate processes traditionally handled manually. Thus, improving overall supply chain efficiency and responsiveness. This ability is particularly vital in industries that experience frequent disruptions due to inadequate transportation infrastructure and irregular power supply (Afolabi & Mgbemena, 2023). AI technologies also contribute to greater resilience of the supply chain by providing manufacturers with tools for proactive decision-making and enhanced operational precision (Ali & Okafor, 2022).

Studies have shown that AI-driven automation can reduce operational costs and enhance logistics management, which is critical for Nigerian firms aiming to meet domestic demand and compete in global markets (Chen et al., 2020). In addition to operational efficiencies, AI robots offer innovative solutions for quality control and inventory management. By integrating machine learning algorithms, firms can monitor product quality and reduce waste, which is particularly significant for Nigeria's manufacturing sector, where waste management is a key issue (Singh & Shankar, 2021). As more Nigerian firms recognize the potential of AI for supply chain optimization, an increasing number of manufacturers are exploring ways to leverage this technology to enhance competitiveness, meet regulatory standards and increase customer satisfaction (Zhu et al., 2022).

Despite the potential of AI to transform supply chains, significant challenges remain, such as high implementation costs, lack of infrastructure, and limited technical expertise (Gong et al., 2022). This study explored the transformative impact of AI robots on supply chain effectiveness of food and beverages firms. The primary purpose was to investigate the relationship between AI robots and supply chain effectiveness of food and beverage manufacturing firms in Nigeria. The study decomposed supply chain effectiveness into delivery performance, logistics cost, and asset management.

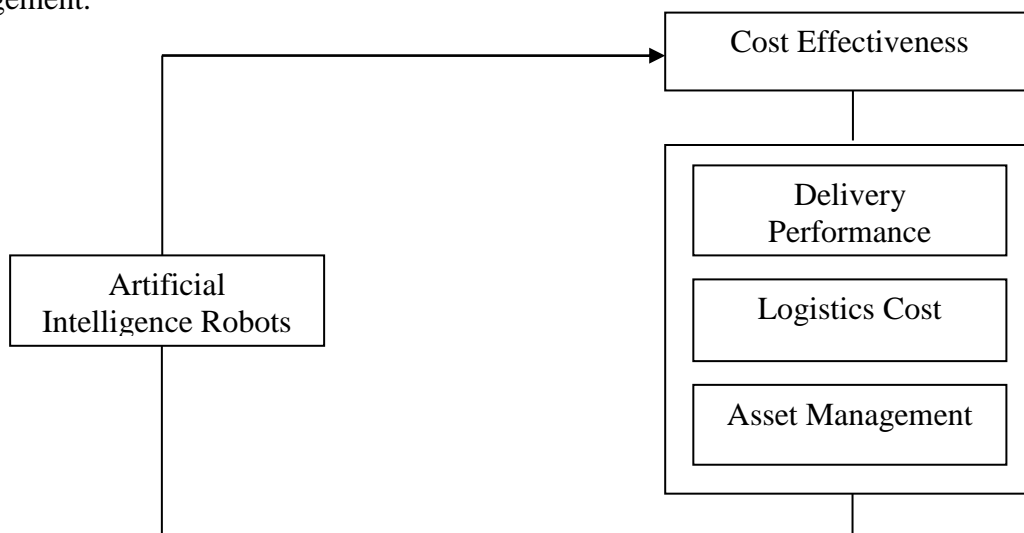


Fig. 1: Conceptual framework of relationship between artificial intelligence robots and supply chain effectiveness of food and beverages manufacturing firms in Nigeria

Theoretical Foundation: Value Chain Theory

Value chain theory was founded by Michael Porter in 1985 (Christopher, 1992). In his 1985 book "Competitive Advantage", Michael Porter introduced a generic value chain model that comprises a sequence of activities found to be common to a wide range of firms (Christopher, 1992). To better understand the activities through which a firm develops a competitive advantage and creates shareholder value, it is useful to separate the business system into a series of value-generating activities referred to as the value chain (Oteki & Sakwa, 2020).

In supply chain, a value chain disaggregates a firm into strategically relevant activities in order to understand the behavior of costs and existing and potential source of differentiation (Oteki &

Sakwa, 2020). In Porter's model, value chain consists activities performed by organizations to design, produce, deliver and support their products. Porter (1985) distinguishes between primary activities covering inbound logistics, operations, outbound logistics, marketing and sales, service in the core value chain creating directly value and support activities including procurement, technology development, human resource management and firm infrastructure.

Implementation of AI robots is explained by the value chain theory. As assumed in the theory, the various sets of activities in the organization are created to create value for consumers. These activities demarcate the firm into various sections, and technology is deployed to some degree in every section. Thus, change in technology bring about new configurations to the value chain and impact the effectiveness of operations (Simichi-Levi, 2000). Also, the development of Internet and technologies which enable real-time information sharing support the building of closer links with customers, suppliers and third-party vendors. Therefore, value chain theory is appropriate for underpinning this study.

Concept of Artificial Intelligence Robots

Artificial intelligence (AI) robot is a robotic system that incorporates AI to sense, process, and act upon information from its environment. AI robots perform tasks that typically require human intelligence, including visual perception, speech recognition, decision-making, and language translation, by leveraging algorithms, machine learning and data analytics to autonomously execute complex actions and improve their performance over time through experience (Russell & Norvig, 2020).

AI robots utilize AI technologies such as natural language processing, machine learning, and computer vision to understand and interact with their surroundings. The goal is to achieve a level of autonomy that allows the robot to perform tasks without human intervention, adapting to new situations as they arise (McCarthy et al., 2019). AI robots are transforming warehouse operations by enhancing efficiency, accuracy and productivity. Their significance can be observed in various aspects of warehouse management.

AI robots operate 24/7 without need for breaks, significantly increasing throughput of warehouse operations. They handle repetitive tasks such as picking, packing and sorting with high speed and accuracy, reducing time required to fulfill orders (Wurman et al., 2008). Additionally, by utilizing AI algorithms and machine learning, robots accurately identify, pick and place items. This reduces the chances of human errors in inventory management and order fulfillment, leading to higher customer satisfaction and lower return rates (Scott, 2023; Kane et al., 2017).

Concept of Supply Chain Effectiveness

Supply chain effectiveness is the degree to which a supply chain is able to meet the needs of customers in terms of responsiveness, flexibility, reliability and cost-effectiveness (Mentzer et al., 2001). Fisher (1997) describes supply chain effectiveness as the ability of a supply chain to consistently meet customer requirements in terms of product availability, lead time and service quality while optimizing costs and resources. According to Chopra and Meindl (2021), supply chain effectiveness refers to "the extent to which a supply chain achieves its goals of providing maximum value to customers while utilizing resources efficiently."

A supply chain is effective if it fulfils timely delivery products to consumers. By implementing efficient supply chain practices and continuously monitoring performance metrics, companies enhance competitiveness and ensure sustainable business growth. Measuring effectiveness requires paying attention to such indices as on-time delivery and product freshness helps in maintaining product quality and reducing the risk of spoilage (Dyckhoff et al., 2004).

Moreover, customer satisfaction is directly influenced by supply chain effectiveness. Consumers expect consistent availability of products and timely delivery. Efficient supply chains enable companies meet customer demands promptly, leading to higher satisfaction levels and customer retention (Christopher, 2016).

Measuring supply chain effectiveness is essential for cost control, quality management and customer satisfaction. Supply chain effectiveness is operationalized into various measures. According to Nsobiari et al. (2018), customer satisfaction, quality customer service and on-time delivery are qualitative measures; and lower cost, higher sales volume, higher profit, inventory investment and higher percentages in return on investment are quantitatively measures of supply chain effectiveness.

Similarly, Floriano (2016) identified asset management, contribution margin, profitability, logistics costs, delivery performance, responsiveness and flexibility as measures of supply chain effectiveness. This study adopted delivery performance, logistics cost and asset management to measure supply chain effectiveness.

Delivery performance

Delivery performance is a crucial metric of supply chain management that directly impacts customer satisfaction and competitiveness (Chopra & Meindl, 2016). Sarkis (2012) defines delivery performance as an organization's ability to fulfill customer orders within specified timeframes while maintaining quality standards. Christopher (2016) emphasizes the significance of delivery performance, highlighting its role in evaluating the reliability of an organization in delivering products according to predetermined criteria such as timeliness, completeness and accuracy.

Timely delivery is a key component of delivery performance, as delays lead to customer dissatisfaction and increased costs (Chopra & Meindl, 2016). According to Sarkis (2012), on-time delivery is a critical metric used to assess delivery performance, as it reflects the firm's ability to meet promised delivery dates. To achieve optimal delivery performance, firms focus on enhancing logistics and supply chain capabilities. This involves streamlining order processing, optimizing production scheduling, and improving transportation (Chopra & Meindl, 2016).

By leveraging technology and implementing efficient processes, firms minimize lead time, reduce errors, and enhance overall delivery performance (Sarkis, 2012). Delivery performance plays a critical role in determining the success of organizations in today's competitive business environment. By prioritizing timeliness and order accuracy, organizations enhance customer satisfaction, build brand loyalty, and gain a competitive edge in the market.

Logistics cost

Logistics cost comprises all expenses incurred in the course of sourcing raw material to delivering finished products to customer. For an organization to have efficient warehouse operation, it must be able to reduce its cost structure. Reducing the cost structure invariably means being cost efficient, which has to do with saving money by changing warehouse processes to work in a more economical way. This is done to improve the bottom line by decreasing procurement costs and improving efficiencies across board (Jeff, 2022).

The ability to decrease costs and increase the bottom line by making processes more efficient is a key to the value that procurement offers organizations (Hollinger, 2021). Effective business management requires making strategic decisions. Business leaders often look for opportunities to minimize costs to maximize revenue. However, it is important to make informed decisions to avoid compromising quality or business practices.

The fundamental focus of all businesses is to improve customer value and revenue generation capabilities, which in turn increases profit margins (Varum, 2020). Cost-efficiency is one of the most commonly used strategies to increase profit. The more cost-efficient decisions that business owners make, the more profitable the company becomes. With regard to logistics, companies assess efficiency by comparing costs incurred in terms of storage, inventory management and movement of goods within and outside the organization, against revenue generated.

Asset management

Asset management is the process of developing, storing, operating, maintaining, and selling off assets in a cost-effective manner. It is the systematic method of managing and tracking assets. Overall, asset management successfully and efficiently controls life cycle of assets. Assets are managed, invested in, and eventually phased out in favor of future investments rather than being sold rapidly like inventories (Bharadwaj, 2022).

Asset management is a must for every business. In this manner, its stakeholders would be aware of the resources that can be used to provide the best results. Assets can be divided into two groups: fixed assets and current assets. Assets bought for long-term usage are referred to as fixed or non-current assets, whilst those that may be turned into cash quickly are known as current assets (Bharadwaj, 2022).

Successful asset management is crucial to logistics firms. Businesses frequently move assets between warehouses or locations, which raises the risk of asset loss and theft. For this reason, asset tracking is crucial. An inappropriate approach to logistics management can have a negative financial effect on firms. This is especially true in the era of asset tracking and logistics asset management technologies like barcode, RFID, and Quick Response Tags (Bharadwaj, 2022).

Artificial Intelligence Robots and Supply Chain Effectiveness

In Taiwan, over ninety-eight percent of enterprises are SMEs, and the cost of introducing automated warehouse management systems with digital tools and transformation is difficult, hence, are not easily adopted (Tsai & Lee, 2023). Therefore, Tsai and Lee (2023) investigated humanized applications of AI in a semi-automated warehouse management system in Taiwan to address cost issues, including new system implementation switching time and cost.

The semi-automated warehouse management systems applied a new methodology, including machine learning with humanized applications of artificial intelligence technology such as image identification and voice recognition, to allow corporate employees to easily adopt it without learning overly complicated tools or new working processes. Tsai and Lee (2023) observed that new warehouse management system reduce warehouse error rate, improve turnaround time and increase customer satisfaction and employee engagement. Applying artificial intelligence improve employees' work quality and reduce cost of overtime for enterprises and resources saving with sustainable management for enterprises.

Tubis and Rohman (2023) examined smart warehouse in industry 4.0 in Poland. The scholars observed that the development of Industry 4.0 and digitization and automation of manufacturing processes have created a demand for designing smart warehouses to support manufacturing processes in Poland, and warehousing being one of the fundamental processes in the supply chain, is responsible for handling inventory. Thus, efficient execution of warehouse operations determine effectiveness of flow of goods.

Angammana and Jayawardena (2022) investigated the influence of AI on warehouse performance. The study focused on influence of AI on warehouse performance. The study illustrate the influence of machine learning, robotics, the Internet-of-Things (IoT), and fuzzy logic on warehouse performance. In Nwokah (2022), it was established that warehouse automation techniques improve retail success of corporate chain stores; while Johan and Christoffer (2017) affirm the economic impact of autonomous vehicles in the logistics industry in Sweden.

In view of the studies reviewed above, this study tested the following hypotheses:

- H01:** There is no significant relationship between AI robots and delivery performance of food and beverages manufacturing firms in Nigeria.
- H02:** There is no significant relationship between AI robots and logistics costs of food and beverages manufacturing firms in Nigeria.
- H03:** There is no significant relationship between AI robots and asset management of food and beverages manufacturing firms in Nigeria.

Methodology

This study aligned with the positivist philosophy; applied a quantitative methodology and adopted a survey research design. The population of the study comprised 17 Quoted Food and Beverages Manufacturing Firms in Nigeria. The entire population was studied. 5 managers (warehouse, ICT, transportation, sales, and general manager) from each of the 17 food and beverages manufacturing firms making a total of 85 respondents provided data for the study using a 16 item questionnaire structured in Likert scale. However, only 77 respondents provided valid data used for the analysis.

The reliability of the research instrument was determined via Cronbach's Alpha reliability test, subject to a threshold of 0.70 set by Nunally (1978); while its validity was determined through Principal Component Analysis (PCA) (see table 1 for results of reliability and validity tests). To determine the impact of AI robot on supply chain effectiveness, the Pearson Product Moment

Correlation (PPMC) was used to test three null hypotheses, with the aid of Statistical Package for Social Sciences (SPSS) version 22.0.

Table 1: Reliability and Validity Tests

S/N	Variables	Number of Items	Cronbach's Alpha Coefficients	Factor Loadings
1	Artificial Intelligence Robots	4	0.827	0.771
2	Delivery Performance	4	0.749	0.799
3	Logistics Costs	4	0.742	0.724
4	Asset Management	4	0.809	0.831

Source: SPSS Output form field data

Results of the Cronbach's Alpha analysis in Table 1 revealed that all the variables in the study produced high Cronbach's Alpha coefficients. This evidences that, there is inter-item consistency among the variables in the study. Again, all the variables have high factor loadings greater than 0.4, indicating that the items and variables in the questionnaire measured what they were supposed to measure. These loadings indicated that there is no cross-loading hence there is discriminant validity.

Test of Hypotheses and Results

Table 2: Relationship between AI robots and delivery performance

		Artificial Intelligence Robots	Delivery Performance
Artificial Intelligence Robots	Pearson Correlation	1	.662**
	Sig. (2-tailed)		.000
	N	77	77
Delivery Performance	Pearson Correlation	.662**	1
	Sig. (2-tailed)	.000	
	N	77	77

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

The strength and direction of the relationship between AI robots and delivery performance is indicated by the Pearson Correlation Coefficient of 0.662 in Table 2. This shows that AI robots have strong positive relationship with delivery performance. Furthermore, significance of the relationship is shown by the probability value of 0.000 which is less than the critical value (0.05), indicating that the relationship between the variables is statistically significant. In other words, AI robots have strong, positive and statistically significant relationship with delivery performance at ($r = 0.662$, $N = 77$, $p = 0.000 < 0.05$). In view of this result the null hypothesis was rejected.

Table 3: Relationship between artificial intelligence robots and logistics costs

		Artificial Intelligence Robots	Logistics Cost
Artificial Intelligence Robots	Pearson Correlation	1	.328**
	Sig. (2-tailed)		.004
	N	77	77
Logistics Cost	Pearson Correlation	.328**	1
	Sig. (2-tailed)	.004	
	N	77	77

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

The strength and direction of relationship between the AI robots and logistics cost is indicated by the Pearson Correlation Coefficient of 0.328 in Table 3. This shows that AI robots have weak positive relationship with logistics costs. The significance of the relationship is shown by the probability value of 0.000 which is less than the critical value of 0.05. This suggests that the relationship between AI robots logistics costs is statistically significant. In other words, artificial intelligence robots have weak, positive and statistically significant relationship with logistics costs at ($r = 0.328$, $N = 77$, $p = 0.000 < 0.05$). Thus, the null hypothesis was rejected.

Table 4: Relationship between artificial intelligence robots and asset management

		Artificial Intelligence Robots	Asset Management
Artificial Intelligence Robots	Pearson Correlation	1	.576**
	Sig. (2-tailed)		.000
	N	77	77
Asset Management	Pearson Correlation	.576**	1
	Sig. (2-tailed)	.000	
	N	77	77

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

The strength and direction of relationship between AI robots and variable and asset management is indicated by the Pearson Correlation Coefficient of 0.576 in Table 4. This value shows that AI robots have moderate positive relationship with asset management. The significance of the relationship is shown by the probability value of 0.000 which is less than the critical value of 0.05, indicating that the relationship between variables is statistically significant. In other words, AI robots have moderate, positive and statistically significant relationship with asset management at ($r = 0.576$, $N = 77$, $p = 0.000 < 0.05$). Hence, the null hypothesis was rejected

Discussion of Findings

The statistical analyses conducted to determine the direction and strength of relationship between AI robots and measures of supply chain effectiveness shows that AI robots have strong, positive relationship with delivery performance; weak, positive relationship with logistics costs; and moderate, positive relationship with asset management. In addition, all the relationships showed statistical significance.

These results align with the report of Tsai and Lee (2023) that warehouse management systems applying artificial intelligence could improve employees' work quality and reduce the cost of overtime for enterprises and resources saving with sustainable management for enterprises. The results also support that of Tubis and Rohman (2023) found that Industry 4.0 technological solutions, such as Internet-of-Things, augmented reality, RFID, visual technology, and other emerging technologies; and autonomous and automated vehicles improve warehouse operations.

Additionally, the finding align with the report that artificial intelligence (machine learning, robotics, Internet-of-Things, and fuzzy logic) has strong influence on warehouse performance (Angammana & Jayawardena, 2022); and that warehouse automation techniques strongly impacts retail success of corporate chain stores (Nwokah, 2022). Furthermore, the findings of this study cohere with the findings of Johan and Christoffer (2017) that autonomous vehicles strongly impact logistics operations.

Conclusion and Recommendations

Based on the findings of this study and the extent to which they support findings of previous studies, the study concludes that application of AI robots in warehousing has positive and significant relationship with supply chain effectiveness of food and beverages manufacturing firms in Nigeria. This relationship is expressed in the positive and significant relationships AI robots' application has with delivery performance, logistics cost, and asset management quoted food and beverages manufacturing firms in Nigeria. Therefore, the study recommends that, food and beverages manufacturing firms in Nigeria should invest more in the integration of AI technology into warehousing in order to enhance delivery performance, logistics cost savings, and asset management.

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