Analyzing the Impact of Technological Innovations on Green Logistics for Sustainable Last-Mile Delivery of Perishable Farm Produce

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DOI: https://dx.doi.org/10.47772/IJRISS.2025.906000179

Received: 27 May 2025; Accepted: 02 June 2025; Published: 05 July 2025

ABSTRACT

The rapid evolution of technology is reshaping the logistics industry, particularly in addressing the challenges of sustainable last – mile delivery for perishable farm produce. This paper explores the role of technological innovations in advancing green logistics, emphasizing their impact on reducing environmental footprints, improving efficiency, and minimizing waste. Key technologies such as internet of things (IoT) sensors, artificial intelligence (AI) for route optimization, electric and autonomous vehicles and blockchain for supply chain transparency are analyzed. The study's population consists Registered Manufacturing Companies in Nigeria. 10 Agribusiness companies in Nigeria was purposefully selected based on their degree of expertise in food security and sustainability. The questionnaire was constructed scientifically to depict the mind of the respondents. Multiple Regression and percentages were used to analyze the data at 0.05 level of significance. The findings underline the potential of technology-driven green logistics while addressing the unique demands of handling perishable goods. This finding provides valuable insights for stakeholders in agriculture, logistics and technology sectors aiming to create resilient, eco-friendly supply chain.

Keywords: Technological Innovation, Green Logistics, Last-mile Delivery, Sustainable.

INTRODUCTION

The effective and efficient delivery of public goods is embedded in the concept of Logistics. Logistics is an integrated management of goods/services and information flow to ensure effective and efficient delivery of goods and services to the final customers. (Andrzej, 2012). Logistics, at a minimum, involves the movement of labor, equipment, and materials—each representing a form of demand constrained by supply chain capacity and the efficiency of logistical operations. It serves as the critical link throughout the entire supply chain, including within the agricultural sector, effectively acting as the "connecting arrows" that bind the system together, (Robert, 2021). The Nigeria transport and logistics sector plays a crucial role in the agriculturally based supply chain. However, over the years, the sector have been fraught with some challenges which includes: poor road design, poor maintenance of transport infrastructures, lack of proper interconnectivity between modes, inadequate investment, low adoption of technological solutions etc. which affect product distribution, especially the perishable farm produce (e.g. tomatoes, pepper, fruits, vegetables and some other farm crops with low life span) which in turn affect product availability in the market and farmers incurring losses.

Globally, Nigeria ranks low in the quality of its logistics and transportation infrastructure, which have impacts on the ease of delivery of goods. According to the logistics performance index (LPI) in 2018, Nigeria was ranked 103 positions out of 167 countries, which is relatively low.

Karim (2020) also said that it is generally accepted at the macro level that the countries logistics performance has a major impact on the economic performance of the country economy. This implies that Nigeria logistics performance and the country economic performance is relatively poor based on their position according according to the LPI ranking.

However, an effective and efficient transport system for the produce is a necessity. As noted by (Suzana et.al 2007) the exchange and delivery of perishable farm produce /goods both in small and large quantities would not

be challenging when there are effective and efficient technological innovation that will enhance the running workforce of the logistics and the transport sector.

What technological innovation then needs to be adopted to improve the agricultural sector efficiency? How does the adoption of these innovations enhance a timely delivery of perishable farm produce? Realizing the significance of technological innovations with the agriculture supply chain/ logistics, this study hereby seeks to identify the effect of the adoption of the technological innovation on the distribution of last mile agricultural produce and what technological innovation needs to be adopted to improve the agricultural sector efficiency.

LITERATURE REVIEW AND CONCEPTUAL UNDERSTANDING.

Innovation in logistics and transportation

Innovation can be seen as a strategic tool for leveraging financial resources to generate profit-enhancing ideas and solutions (Antonowicz, 2014). It is a process that transforms identified opportunities into novel concepts and implements them in practical ways (Björklund & Forslund, 2018). This transformation can involve changes to a business's current offerings, business models, or service structures with the goal of enhancing customer accessibility and overall experience (Antonowicz, 2014). The motivation for innovation often lies in the desire to reduce operating costs and increase profitability (Soosay & Hyland, 2004).

Technological innovation, in particular, plays a significant role in various aspects of supply chain logistics, including processes, inventory management, and transportation solutions (Bajec, 2012). Bajec outlines three primary drivers of innovation in logistics: the adoption of new technologies, the formation of new collaborative models, and the application of new knowledge. As technology continues to evolve rapidly, businesses must adapt their processes accordingly to remain competitive (Grawe, 2009). Grawe also highlights a positive relationship between technological innovation, logistical capabilities, and an industry's ability to efficiently manage production activities.

Furthermore, integrated logistics and the development of information and communication technology stands to re-shape the world's trading patterns and subsequent physical trade flows (Vasiliauskas & Jakubauskas, 2007). To be internationally competitive, industries organize strategic worldwide networks that can deliver efficient and high-quality responses to demand from any part of the world market. More importantly, supply chain management processes plays a big role in customer satisfaction, which is more important than low product costs.

The agro-based industry

Agro-industry is an interconnected activity i.e.: production, processing, transportation, storage, funding, marketing and distribution of agricultural products. Agro-based industries are businesses that process raw materials derived from agriculture into finished or semi-finished products. These industries rely on crops, livestock, and other agricultural outputs to produce goods such as food, beverages, textiles, and biofuels. They play a crucial role in adding value to agricultural products, generating employment, and contributing to economic development, especially in rural areas (FAO, 2017). Examples include dairy processing, fruit and vegetable canning, sugar production, and cotton textile manufacturing.

The success of agro-based industries depends on factors like the availability of raw materials, transportation infrastructure, technology, and market access (World Bank, 2020). By linking agriculture with industry, they help in reducing post-harvest losses and increasing the income of farmers.

Production and delivery of perishable goods in the Agro-based industries.

Perishable is a term used in the context of goods that has short life span. Farm produce such as tomatoes, pepper, fruits and vegetables are examples of goods that are likely to get spoil within a short frame of time. It is envisaged that there is an increase in the demand of these goods because it often happens to be part of our everyday consumption. Increasing the production of these goods is one way to fulfill the need and demand of the consumers. In addition, waste reduction at every stage of the goods with the aid of a good supply chain/logistics system can also be an option to get advantage from the increased production. Major operational challenge that

farmers have in the agricultural industries is the waste and loss which occur due to inefficiencies in production, storage, handling, and transportation of this goods to the consumers. (Vishal et.al, 2017). Many good technological innovations that can enhance the delivery of these goods and reduce losses has not been implemented. Also, lack of proper logistical planning and bad transportation system is a major challenge in the supply of these goods within cities, towns and villages located within the axis of the southwestern Nigeria. It is seen that the lack of good technological innovations both in the logistics and transportation sector is a major problem that increases the loss and wastage of these farm produce immediately after the post-harvest period till the point of transporting them to the consumers. (Vishal et.al, 2017).

Transportation and Logistics challenges in the agro-based industries.

The development of transportation in the development of economies around the world cannot be overemphasized. Transportation improves the operations of the agro-based industry through improved accessibility to both geographical and economic regions. In the developing cities in the southwestern Nigeria, especially in the rural areas where farming activities are carried out, a good transportation operation facilitates the transfer of farm produce to markets, encourages increased production, distribution and timely delivery of goods to the consumer. However, in the absence of a good road network, lack of sustainable innovations and management problem in the transportation industry, farmers in the agro-based industry would be discouraged to produce in large quantities because of the fear of the perishable nature of their farm produce. There is a fear that the farm produce might not get to the place where it is being demanded before it begins to get spoil. (Olusogo et.al, 2018)

Supply chain management (SCM) processes involving relations between humans, nature, technology and resources are more and more complicated every year. (Nilsson, 2006). It is seen that the lack of good and adequate equipment in the logistics sector of the agro-based industries has led to many loss of goods and profit. Crop losses, especially along the post-harvest food supply chain, have been identified as one of the major causes of food shortage problems in most developing countries and in Nigeria in particular. Vegetable farmers such as those that grow tomatoes often record great amount of produce loss which translates to a waste of resources, a reduction in their income and ultimately their welfare. Several factors which are associated with the logistics and transportation operation in the agro- based industry led to this wastage and losses. (Abimbola, 2014).

The lack of good and effective modern storage facilities, good road network, good vehicles and good logistical channel/system has led to the loss of goods in the agro- based industry. For instance, when farmers decide to take their produce to the market, they are often constrained by problems of transportation such as bad roads, inefficient mode of conveying their produce to the market, the use of dilapidated trucks and coupled with the lack of effective and adequate modern storage facilities. All these problems leave the farm products prone to damages and post-harvest losses. The lack and inadequacy of sustainable transport technologies and logistical tools is thereby seen as a major challenge in the agro-based industry (Kader, 2005). However, the lack of enough fund or capital that can be used for the implementation of such technological innovations by farmers in the agricultural sectors/ agro-based industry could also a challenge. (Mona et.al, 2020)

Technological innovation as a solution to ineffective transport and logistics in the agro-based industries.

One of the country's agricultural policy thrust specifies that farmers be encouraged to use simple but effective on-farm and off-farm storage facilities and agro-processing technology in order to add value to farm produce and increase their shelf life. In line with this, the Nigerian Stored Products Research Institute (NSPRI) together with Food and Agricultural Organization (FAO) developed techniques for the storage of fruits, vegetables, tomatoes and other perishable type of goods. The founder of Meritos farm, Lagos, Toluwalope Daramola and the Agbekoya farmers society emphasized that the southwest governors and stake holders in the agricultural sector should provide farmers with modern and advanced equipment's and devices. (Gbenga Akinfenwa, 2022). In view of this, the implementation of good technological techniques and innovation that could help increase the shelf-life of the crops and make them stay longer before been sold is encouraged in the agro-based industry. (Adesina, 2012). Beyond the usage of Just in Time (JIT), the concept of the 4PL in logistics and the construction of good roads and usage of vehicles in transportation, there are advanced sustainable technological innovations both in the logistics and transport sector that will facilitate better operation and timely delivery of products,

especially perishable farm produce in the agro-based industry.

The innovation of digital and robotic technologies will bring about an advanced packaging process in logistics. Automation of simple activities of the supply chain, such as packaging can increase efficiency and can assist in developing new-value added services in the agro-based industry. Nanotechnology is an emerging technology used with perishable food packaging to retain it freshness, minimize waste, ensure the products safety and improve it quality. Intelligent packaging protect the quality of these perishable farm products. (Mona et.al, 2020). For instance the usage of palm woven basket used by farmers for the package of perishable goods like tomatoes, and vegetables, has rough edges that pierce or damage the produce when utilized. So, the usage of plastic crates which are durable and reusable are encouraged to adopt. It also helps reduce transport damage and thereby extend shelf life of these produce/goods. . (Lorliam and Ugoo, 2022).

Block chain is also a technological means in logistics that can provide innovative resolutions for maintaining the quality of the farm produce being produced. Block chain technology is efficient in sorting out the issues related to agricultural food supply chain traceability by ensuring the safety of farm produce. The major aim of using block chain technology in the food supply chain is that it stores the food information in the form of transactions, which are evenly distributed, and seems to be transparent. The transaction in the block chain network can be validated while all the nodes can trace the food information for achieving transparency and traceability for food safety. Several blocks are used for packaging the transactions in the food supply chain. The data in the block chain are kept with safety assurance without any sort of manipulation. (Mona et al., 2020).

The implementation and usage of refrigerated vehicles will also enhance the operation system of the agro-based industry. Transporting perishable goods to market on such a poor road network and without suitable conveyance, becomes a major difficulty for both growers and wholesalers. The rail and road systems, are the two main modes of transportation available to domestic carriers and handlers of fresh produce in Nigeria. Transporters, on the other hand, grumbled about the rail system's lack of availability and unusual delays, therefore all handlers chose the road system for their regular and long-distance haulage. As a result of this problem, there are unnecessarily long delays in bringing the goods to market. The wobbly nature of most vehicles, along with the poor state of most roads, also causes a great deal of mechanical damage to the produce before it arrives at its destination. In view of all these problems, the innovation of refrigerated containers, trailers and truck that drive on relatively excellent highways is not only convenient, but also beneficial in protecting perishable goods quality. (Lorliam and Ugoo, 2022)

The innovation of evaporative cooling system for the storage of perishable goods in the agro-based industry will also enhance the logistics operation in the agro-based industry. (Lorliam and Ugoo, 2022).

Road transport covers the widest network in the country, it is easy to expand and it provides the most flexible services. Therefore, the construction and innovation of good road networks with advanced technological equipment’s will also enhance timely delivery of public goods. Also, the construction of fly-overs on the road with innovation and procurement of electric vehicles to make use of it as their pathway, will also enhance the delivery of public goods from the agro-based industry to the public/consumer. (Oluwaseyi et.al, 2018).

Cost Analysis

The non-availability of sustainable technological innovations in the agro-based industry will make farmers sell their products at a reduced cost as they may not be able to keep their perishable product/goods for an extended period of time. This then has a grave effect on their income and the profit they are been able to generate. (Adesina, 2012). However, the initial investment as well as the ongoing operating cost of these advanced technological innovation maybe prohibitively expensive for most developing producers in the agro-based industry (Lorliam and Ugoo, 2022). Therefore, there is a need to measure all the cost, especially production cost and logistics cost and then calculate the price at which products will be sold out when there is a procurement and usage of advanced technological innovations in the agro-based industry.

Though, the cost at the farm level is made up of costs for production activities while the factors that affect the cost at the trade level is based on the infrastructural condition. So, in the absence of technological innovations in the logistics and transport sector of the agro- based industry, a basket of tomatoes or pepper or fruits, that is

supposed to be sold at 8000, might later be sold for 6500 to the consumer. This will happen because 100 pieces of tomatoes might later reduce to 75 pieces of tomatoes before getting to the place of demand due to high risk of damage and loss before and during the transportation of the goods, which then take away or reduce the profit of farmers in the agro-based industry.

When sustainable technological innovations in the logistics and transport sector are implemented in the agro-based industry, it will enhance a timely delivery of goods/products and also cancels or reduce loss and damage of these perishable farm produce. However, because of the high cost of funds used in the procurement of these technological innovations, there is a high possibility that the cost of goods and delivery will be more expensive. For instance, a basket of tomatoes that is been sold for 8000 might be sold for 10000. Although, both the producer and the consumer will get maximum satisfaction. The producer will get and make the maximum profit they should make while the consumers will also be rest assured that their goods will be delivered to them in a good state and it will be timely. This then, shows that sustainable technological innovations tend to increase the cost incurred on every produce. Furthermore, the magnitude of logistics cost does vary, depending on the location of the production which will affect the cost of transport. It is also important to know that the selling price of these products is determined by the producer in accordance with the level of the market demand of the product. (Kuncoro and Dwi, 2019).

MATERIALS AND METHODS.

The study area for this research is the southwestern Nigeria. The southwest of the country Nigeria is the one of the six geopolitical zones of Nigeria representing both a geographic and political region of the country. It comprises of six states- Ekiti, Lagos, Ogun, Osun and Oyo. It is majorly a Yoruba speaking area, although there are different dialects even within the same state. The weather conditions vary between the two distinct seasons in Nigeria; the rainy season (March-November) and the dry season (November – February). The area lines between longitude 2031 and 60001 east and latitude 6021and 80371 N with a total land area of 7,818km^2. National population commission, (2007) reported that 2751189 people lived (14049594 males and 13462298 females) in southwest, Nigeria. The temperature zone ranges between 21 and 28 degree centigrade with high humidity of 77 percent. Hence, crops and livestock production are done with little problems in the area. The major occupation of the people is agriculture. Other occupations include: trading, driving, carpentry etc. (Oluwatosin and Ojo, 2017). Primary and secondary source of data collection was used to collect data. The study's population consists of Registered Manufacturing Companies in Nigeria. 10 Agribusiness companies in Nigeria were purposefully selected based on their degree of expertise in food security and sustainability. Data were collected using a well-constructed questionnaire was scientifically employed to depict the mind of the respondents. Multiple Regression was used to analyze the data at 0.05 level of significance.

DISCUSSION OF FINDINGS

Table below shows a R value of 0.351, denoting a positive relationship between the dependent and independent variable, a R^2 of 0.124, this implies the variation in the dependent variable is accounted for by the independent variables; this shows that about 12.4% of the variance in Reducing Environmental Footprints is explained by the model which means most of the variation in environmental footprint reduction is due to factors not included in this model. The F-statistic tests whether the overall regression model is a good fit, F= 3.348, and its significance indicate that the model is statistically significant with at least one predictor having a significant relationship with the dependent variable. The independent variable on the other hand implies that Blockchain for supply chain transparency has a significant positive impact ($p = 0.010$) and is the strongest predictor in the model. This suggests that improving supply chain transparency through blockchain may effectively support environmental sustainability this is corroborated by a study published in 2024 by Lyu Zhang & Magnus Fröhling highlights that integrating blockchain with Life Cycle Assessment (LCA) provides stakeholders with detailed and transparent information about environmental impacts. This integration enables companies to identify environmental hotspots, enhance sustainable supply chain management, and optimize emission reduction efforts. AI for route optimization and Electric and Autonomous Vehicles show weak or marginally significant impacts (p-values of 0.061 and 0.071 respectively), indicating they may contribute somewhat but not strongly within this dataset. IoT Sensors have no significant effect on reducing environmental footprints in this model ($p = 0.499$) this can be supported by *Business Insider 2025* that while IoT technologies are increasingly used in agriculture

to enhance efficiency and sustainability, challenges such as high costs and rural connectivity issues hinder widespread adoption, limiting their impact on environmental footprint reduction. The implication of this result is that the adoption of technological innovation under consideration still has a low usage which in turn influences it's effect on the sustainability of the green logistics in last mile delivery of perishable farm produce. It is also important to note that reducing the environmental footprint is a complex phenomenon which is affected by other factors. This finding is buttressed by the work of kelechi ugwu et al, 2024.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.351[a]	.124	.087	.510

a. Predictors: (Constant), Blockchain for supply chain transparency, Electric and Automonous Vehicles, AI for route optimization, IoT Sensor

ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	3.483	4	.871	3.348	.013[b]
	Residual	24.707	95	.260		
	Total	28.190	99			

a. Dependent Variable: Reducing Environmental Footprints

b. Predictors: (Constant), Blockchain for supply. chain transparency, Electric and Automonous Vehicles, AI for route optimization, IoT Sensor

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.045	.370		10.943	.000
	IoT Sensor	-.055	.081	-.068	-.679	.499
	AI for route optimization	-.147	.077	-.186	-1.895	.061
	Electric and Automonous Vehicles	.140	.077	.178	1.826	.071
	Blockchain for supply chain transparency	.254	.096	.266	2.631	.010

a. Dependent Variable: Reducing Environmental Footprints

CONCLUSION AND RECOMMENDATIONS

This research study has identified the adoption of technological innovation in green logistics for sustainable last mile delivery of farm produce and proves that technological innovations is essential in creating and achieving a better and an efficient system network in the logistics sector and the transportation structure of Nigeria especially in the last mile delivery of farm produce. It was therefore concluded that there is a wide gap in the adoption of technology in advancing the green logistics sustainability especially in the area of last mile delivery of perishable farm produce. It is therefore pertinent for agro-based industries to invest more in advanced technological innovations that would aid the operational performance of green logistics and at the same time reduce the environmental footprint and sustaining the zero emission. Conclusively, While the model confirms a statistically significant relationship between the chosen technologies and the goal of reducing environmental footprints, only blockchain technology stands out as a clear positive contributor. The overall explanatory power of the model is

low, suggesting that other factors or technologies should be considered for a more comprehensive understanding of what drives environmental improvements in transport management.

It is therefore recommended that government encouraged the implementation of these technological innovations as it opens door for a better and an effective productivity and sustainability in the agro-based industry.

REFERENCES

1. Abimbola, O. A. Post-harvest losses and welfare of tomato farmers in Ogbomosho, Osun State, Nigeria. Vol. 5(2), pp.8-13, June, 2014.
2. Adesina, A. Agricultural Transformation Agenda, ATA: Growing agriculture through value chain, November, 2012.
3. Andrzej Szymonik. Logistics and Supply Chain Management. , Lodz University of Technology, February 2012.
4. Antonowicz, M., Logistic innovations in transport. Scientific Journal of Logistic, 10(1): 21-30, 2014.
5. Bajec, P., An analysis of the logistics innovation development process at logistics service providers, Slovenia: s.n., 2012
6. Björklund, M. and Forslund, H., A framework for classifying sustainable logistics innovations. Logistics Research, 11(1): 1-12, 2018.
7. Gbenga Akinfenwa. The Guardian Newspaper. January, 2022.
8. Grawe, S.J. Logistics innovation: a literature-based conceptual framework. The International Journal of Logistics Management, 20(3): 360-377, 2009.
9. Kader A.A (2005). Increasing food availability by reducing-by-reducing postharvest losses of fresh produce." Proceedings of the 5th international private Postharvest Symposium. Eds.F, Mencarrelll and P. Tountti Acta Hort.P. 682. USA.
10. Kelechi Enyinna Ugwu, Balogun O. navigating supply chain management: Technology Adoption in Southeast Nigeria Breweries, Journal of commerce, Management and Tourism studies 3(39, 231-243, 2024.
11. Kuncoro Harto Widodo and Dwi Ardianta Kurniawan. Cost Structure Analysis in InterIsland Perishable Goods Transport (Case Study: South Konawe Citrus, Southeast Sulawesi, Indonesia). KnE Life Sciences, March 2018.
12. Lorliam Iveren Blessing and Ugoo Tavershima Richard. Postharvest Handling Practices and Treatment Methods for Okra in Nigeria: A Review. Asian Food Science Journal 21(4): 20-33, 2022; Article no. AFSJ.83416 ISSN: 2581-775. April, 2022.
13. Lyu Zhang & Magnus Fröhling, Integration of blockchain and life cycle assessment: a systematic literature review CRITICAL REVIEW Open access Published: 20 September 2024 Volume 30, pages 1–19, (2025)
14. Maria Bjorklund and Helena Forslund., Exploring the sustainable logistics innovation process, industrial management and data systems, 118(1), 204-217, 2018.
15. Mona Haji, Laoucine Kerbache, Mahaboob Muhammad and Tareq Al-Ansari. Roles of Technology in Improving Perishable Food Supply Chains. Logistics, December 2020.
16. Oluwaseyi Joseph Afolabi, Olalekan Adedamola Oluwaji and Temitayo Alice Onifade. , Transportation Factors in the Distribution of Agricultural Produce to Urban Center in Nigeria. Scientific Journal on Transport and Logistics, Vol. 9 No. 1, 2018.
17. Oluwatusin Femi Michael and Ojo Olutope Stephen. ICT-Based Market Information Services Utilization by Small Scale Farmes in South West Nigeria. Department of Agricultural Economics and Extension Services, Ekiti State University, PMB 5363, Ado Ekiti, Nigeria. Report and Opinion 2017; 9 (2).
18. Soosay, C.A. and Hyland, P.W., Driving Innovation in Logistics: Case Studies in Distribution Centres. Driving innovation in logistics, pp. 41-51, 2004.
19. Vishal Kumar, Kapil Kumar, Suresh Chandra and S.K. Goyal. , Perishable and Non-perishable food products roles in environment- A Review. ISSN 394-5168(print), 2454-6445(online), June 2017.
20. FAO. (2017). The future of food and agriculture – Trends and challenges. Food and Agriculture Organization of the United Nations.
21. World Bank. (2020). Enabling the Business of Agriculture 2019. World Bank Group.