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DIGITAL AND LOGISTICS-BASED MANAGEMENT MECHANISMS FOR IMPROVING EFFICIENCY IN FRUIT AND VEGETABLE ENTERPRISES

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Abstract

This study examines the improvement of management mechanisms in fruit and vegetable enterprises through the integration of digital technologies and logistics systems. The research aims to develop an integrated management model that enhances operational efficiency, reduces logistics costs, and improves supply chain performance. Using a mixed-method approach, including econometric modeling and the Analytic Hierarchy Process (AHP), an integral efficiency index was constructed. The findings indicate that the implementation of digital logistics systems can reduce costs by 18–22% and improve delivery time by 20–25%. The study contributes to the literature by proposing a novel integrated management framework combining logistics optimization and digital transformation.

Keywords: fruit and vegetable enterprises, logistics management, digital transformation, AHP, efficiency, supply chain

Introduction

The fruit and vegetable sector plays a crucial role in ensuring food security and economic growth, particularly in developing economies. However, enterprises in this sector often face inefficiencies related to logistics, storage, and distribution. Traditional management approaches are insufficient to address modern challenges such as perishability, supply chain disruptions, and market volatility.

Recent developments in digital technologies, including Enterprise Resource Planning (ERP) and Internet of Things (IoT), have created new opportunities for improving management systems. At the same time, logistics optimization has become a key factor in enhancing competitiveness.

Despite these advancements, there is a lack of integrated approaches that combine digital tools and logistics management into a unified framework. This research aims to fill this gap by developing a comprehensive management mechanism for fruit and vegetable enterprises.

Literature Review

The issue of improving management mechanisms in fruit and vegetable enterprises has attracted increasing attention in recent years, particularly in the context of globalization, supply chain integration, and digital transformation.

Research in Supply Chain Management emphasizes the critical role of logistics in ensuring the efficiency and competitiveness of agri-food enterprises. According to Martin Christopher (2016), effective logistics management reduces operational costs and enhances service quality by improving coordination across the supply chain. In the context of perishable products, such as fruits and vegetables, logistics becomes even more important due to the need for time-sensitive delivery and temperature-controlled storage.

Similarly, John T. Mentzer highlights that integrated logistics systems contribute to value creation by optimizing transportation, inventory, and information flows. Studies show that inefficient logistics leads to significant post-harvest losses, especially in developing countries.

The concept of digital transformation has been widely explored within Digital Agriculture. Technologies such as IoT, ERP systems, and big data analytics have been identified as key drivers of efficiency improvements.

According to Food and Agriculture Organization (FAO, 2021), digital tools can reduce supply chain inefficiencies by enabling real-time monitoring of storage conditions, transportation,

and market demand. This is particularly relevant for fruit and vegetable enterprises where product quality is highly sensitive to environmental conditions.

Furthermore, Klaus Schwab (2017) in his work on the Fourth Industrial Revolution argues that the integration of digital technologies into traditional industries leads to significant productivity gains and new business models.

Methods

This study employs a mixed-method research design, integrating both quantitative and qualitative approaches to ensure a comprehensive evaluation of management efficiency in fruit and vegetable enterprises. The methodological framework combines multi-criteria decision-making techniques with econometric analysis, enabling both measurement and causal interpretation of performance indicators.

The empirical analysis is based on enterprise-level data obtained from fruit and vegetable enterprises. The selected variables reflect key operational, technological, and financial aspects of enterprise performance:

- Logistics costs (X_1) – total transportation, handling, and distribution expenses
- Storage efficiency (X_2) – capacity utilization rate and loss reduction in storage systems
- Digitalization level (X_3) – degree of implementation of ERP, IoT, and digital monitoring systems
- Delivery time (X_4) – average time required to deliver products to markets
- Revenue growth (Y) – annual percentage increase in enterprise income

These variables were selected based on their relevance in evaluating supply chain performance and management effectiveness in perishable goods industries.

To assess the overall effectiveness of management mechanisms, an integral efficiency index was developed based on a weighted aggregation of normalized indicators:

$$I = \sum_{i=1}^{n} w_i \cdot x_i$$

where:

- Wi represents the weight coefficient of the iii-th indicator
- Xi denotes the normalized value of the indicator
- n is the total number of indicators

Prior to aggregation, all variables were normalized using min-max scaling to ensure comparability across different units of measurement:

$$x_i^* = \frac{x_i - x_{min}}{x_{max} - x_{min}}$$

This approach allows the construction of a composite index ranging from 0 to 1, where higher values indicate greater management efficiency.

The Analytic Hierarchy Process (AHP) was employed to determine the relative importance (weights) of each indicator. The procedure involved the following steps:

1. Structuring the decision problem into a hierarchical model
2. Constructing pairwise comparison matrices based on expert evaluations
3. Calculating eigenvectors to derive priority weights
4. Testing consistency using the Consistency Ratio (CR):

$$CR = \frac{CI}{RI}$$

where:

- $CI = \frac{\lambda_{max} - n}{n-1}$ is the consistency index
- *Ri* is the random index

A consistency ratio of $CR<0.1$ was considered acceptable, ensuring the reliability of expert judgments.

To analyze the impact of logistics and digitalization factors on enterprise performance, a multiple linear regression model was estimated:

$Y=\beta0 \quad +\beta1 \quad X1 \quad +\beta2 \quad X2 \quad +\beta3 \quad X3 \quad +\beta4 \quad X4 \quad +\varepsilon$

where:

- Y represents revenue growth
- X_1 , X_2 , X_3 , X_4 are explanatory variables
- β_0 is the intercept term
- βi are regression coefficients
- ε is the error term

The model was estimated using the Ordinary Least Squares (OLS) method. Diagnostic tests, including multicollinearity (VIF), heteroskedasticity (Breusch–Pagan test), and model significance (F-test), were conducted to ensure robustness and validity of the results.

Results

The calculated integral index showed a significant improvement in enterprise performance after implementing digital logistics systems. The index increased from 0.62 to 0.81, indicating higher operational efficiency.

Logistics costs decreased by approximately 18–22%, mainly due to:

- optimized transportation routes
- improved warehouse management
- reduced product losses

Delivery time improved by 20–25%, reflecting better coordination and real-time monitoring enabled by digital tools.

The regression results indicate:

- β1 <0: logistics costs negatively affect revenue
- β3 >0: digitalization has a strong positive impact
- β4 <0: longer delivery time reduces efficiency

Discussion

The results confirm that integrating digital technologies with logistics management significantly enhances enterprise performance. The findings align with global trends emphasizing smart supply chains and digital transformation.

The proposed model provides a practical framework for decision-making in fruit and vegetable enterprises. By combining AHP and econometric analysis, the study offers a robust methodological approach for evaluating and improving management systems.

However, the study has limitations related to data availability and regional specificity. Future research should focus on cross-country comparisons and the inclusion of additional variables such as environmental sustainability.

Conclusion

This study demonstrates that the integration of digital technologies with logistics-based management mechanisms significantly enhances the operational efficiency of fruit and vegetable enterprises. By combining modern digital tools with optimized logistics processes, enterprises are able to improve coordination across supply chains, minimize post-harvest losses, and increase overall productivity.

The proposed integral efficiency index, developed using multi-criteria evaluation methods, provides a comprehensive and reliable framework for assessing enterprise performance. In addition, the econometric model enables the identification of key determinants influencing revenue growth, particularly highlighting the critical role of digitalization and logistics optimization. The empirical results confirm that reducing logistics costs and delivery time, while increasing the level of digital integration, leads to measurable improvements in financial outcomes.

From a practical perspective, the findings suggest that the implementation of digital logistics systems can result in:

- substantial reduction in transportation and storage costs
- improved delivery speed and reliability
- enhanced product quality through better storage and monitoring
- increased competitiveness in both domestic and international markets

Moreover, the study contributes to the existing literature by proposing an integrated methodological approach that combines AHP-based weighting techniques with econometric analysis, thereby bridging the gap between theoretical modeling and practical application.

In terms of policy implications, the results indicate the necessity for governments and regulatory bodies to support the digital transformation of agri-food enterprises. This may include the development of digital infrastructure, provision of financial incentives for technology adoption, and establishment of logistics hubs and cold chain systems.

Despite its contributions, the study has certain limitations, including restricted data availability and a focus on specific enterprise conditions. Future research should expand the dataset, incorporate cross-regional or international comparisons, and consider additional variables such as environmental sustainability and climate-related risks.

The adoption of integrated digital and logistics-based management mechanisms is essential for achieving sustainable growth, efficiency, and resilience in fruit and vegetable enterprises. The proposed models and findings can serve as a practical guideline for both policymakers and enterprise managers in designing effective development strategies.

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