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

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ABSTRACT

The article substantiates digital and logistics-based management mechanisms aimed at improving the efficiency of fruit and vegetable enterprises. The study draws on official statistics of the Republic of Uzbekistan and on international research on cold chain management, food traceability and smart farming. The analysis shows that, despite rapid export growth (USD 2.1 billion in 2025, +36.9%), enterprises continue to lose 20–30% of produce after harvest. The country’s 2,011 cold storage facilities, with a total capacity of 1.14 million tonnes, can hold only about 4.9% of annual output. The author’s estimate puts the storage capacity gap at about 0.5 million tonnes. An integrated model is proposed that links four digital modules (demand forecasting, IoT monitoring of the cold chain, warehouse management based on the FEFO principle and product traceability) with five stages of the enterprise logistics flow. A system of key performance indicators is developed, and the expected economic effect is illustrated with a conditional enterprise-level calculation.

Keywords

fruit and vegetable enterprise, digital management, logistics, cold chain, Internet of Things, warehouse management system, FEFO, traceability, ERP, post-harvest losses.

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Introduction

Fruit and vegetable enterprises operate under conditions that differ sharply from those of most industrial companies. Their raw material is alive, perishable and seasonal; its quality declines from the moment of harvest, and the rate of decline depends on temperature, humidity and handling time. As a result, the efficiency of such an enterprise is determined not only by the volume of production or sales, but above all by how well it manages the physical flow of products and the information flow that accompanies it.

In Uzbekistan the agri-food sector is being transformed in line with the Strategy for the Development of Agriculture for 2020–2030 approved by Presidential Decree PF-5853 of 23 October 2019, which identifies the development of high-value horticulture, modern storage infrastructure and digitalization of agriculture as priorities [1]. Fruit and vegetable exports reached 2.2 million tonnes and USD 2.1 billion in 2025, 36.9% more than in the previous year [11]. At the same time, industry estimates indicate that 20–30% of fruit and vegetable output is lost between the field and the consumer, mainly due to the shortage of cold storage, inadequate packaging and poorly organized transport [12; 13]. Each tonne lost represents not only a loss of revenue for the enterprise, but also wasted water, land, labour and energy.

The first article of this series examined the organization of trade processes at the level of markets and value chains. The present article shifts the focus to the internal management of the enterprise. Its purpose is to substantiate digital and logistics-based management mechanisms that allow fruit and vegetable enterprises to reduce losses and costs and to increase revenue. To achieve this purpose, the following tasks were set: to summarize theoretical approaches to perishable product logistics and digital agri-food management; to assess the state of the storage and logistics base of the sector; and to develop an integrated management model with a system of performance indicators.

Literature review

The theoretical basis of the study is logistics and supply chain management. M. Christopher defines logistics as the process of strategically managing the procurement, movement and storage of materials and finished goods, together with the related information flows, so as to maximize profitability through cost-effective fulfilment of orders [2]. R. Ballou emphasizes that logistics decisions on inventory, transport and location are interdependent and should be optimized as a single system based on the total cost concept [3]. For perishable products this principle is particularly important, because savings on cooling or transport often lead to much larger losses due to spoilage.

The importance of post-harvest management is shown by A.A. Kader, who argues that reducing post-harvest losses of fresh produce through temperature management, careful handling and appropriate packaging is often a cheaper way to increase food supply than expanding production [4, p. 2169–2176]. The FAO report ”The State of Food and Agriculture 2019” estimates that about 14% of food is lost globally between harvest and retail, with losses of fruits and vegetables among the highest; the report also stresses that cold chain and storage deficiencies are a key cause [5].

A significant body of research is devoted to digital technologies in food chains. M.M. Aung and Y.S. Chang review food traceability systems and show that traceability, in addition to food safety, improves inventory management, recall efficiency and trust between chain participants [6, p. 172–184]. A. Kamilaris, A. Fonts and F.X. Prenafeta-Boldú analyse the use of blockchain in agriculture and food supply chains and conclude that it can increase transparency and reduce information asymmetry, although its large-scale use is limited by costs, standards and digital skills [7, p. 640–652]. S. Wolfert and co-authors show that Big Data in smart farming changes not only production but also the organization of the entire chain, shifting power to those who control data [8, p. 69–80].

C.N. Verdouw and co-authors propose the concept of virtualizing food supply chains with the Internet of Things: physical objects are equipped with sensors and represented by virtual objects, which allows enterprises to monitor, plan and control the chain remotely in real time [9, p. 128–136]. R. Jedermann and co-authors develop the concept of ”intelligent food logistics” and the FEFO (first expired – first out) principle, according to which batches are dispatched not by arrival date but by remaining shelf life, estimated from the measured temperature history [10].

The literature therefore shows that digital tools are most effective when they are integrated with the physical logistics system of the enterprise rather than introduced as separate projects. At the same time, studies that link these concepts to the storage and logistics conditions of fruit and vegetable enterprises in Uzbekistan remain scarce, which determines the relevance of this research.

Research methodology

The information base of the study includes official data of the Statistics Agency under the President of the Republic of Uzbekistan [11], legislative acts [1], industry analytical materials [12; 13] and scientific publications [2–10]. Methods of structural and comparative analysis, the total logistics cost approach, the systems approach and modelling were used. The storage capacity gap was estimated by the author as the difference between the capacity required to store 75% of export volume and the existing capacity. The economic effect of the proposed mechanisms was illustrated by a conditional calculation for a typical enterprise; the assumptions of this calculation are stated explicitly.

Analysis and results

Uzbekistan produces more than 23 million tonnes of fruit, vegetables, potatoes, melons and grapes a year, and production has grown by about 3.5% per year in recent years [11; 13]. The structure of production (Figure 1, left) is dominated by vegetables, which account for about half of the total, followed by potatoes, fruits, melons and grapes. Most of these products have a short shelf life at ambient temperature, and their quality depends directly on how quickly they are cooled after harvest. The main indicators of the storage infrastructure of the sector are summarized in Table 1.

Table 1

Key indicators of the cold storage infrastructure of the fruit and vegetable sector of Uzbekistan

Indicator	Value	Comment
Number of cold storage facilities (as of 1 October 2025)	2,011	including refrigerated warehouses of various sizes
Total storage capacity, million t	1.14	—
Average capacity of one facility, t	567.5	calculated by the author
Share of leading regions in capacity, %	Samarkand 16.2; Fergana 14.7; Tashkent 11.4	together 42.3% of capacity
Capacity as a share of annual output, %	4.9 (Tashkent region 6.9; Syrdarya region 2.0)	calculated by the author
Estimated post-harvest losses, % of output	20–30	industry estimates
Share of output that is processed, %	about 15	target of 28% for 2026
Government target for storage capacity by 2027, million t	1.9	—

Source: compiled and calculated by the author based on [11–13].

The data reveal a structural imbalance. On average, the existing storage capacity can hold only about 4.9% of annual output, and the regional spread is wide: from 6.9% in Tashkent region to only 2.0% in Syrdarya region (Figure 1, right). Capacity is concentrated in a few regions, while many producing districts have practically no modern cold storage. The average facility (567.5 t) is small, which limits the use of modern equipment for controlled atmosphere, automated sorting and warehouse management systems.

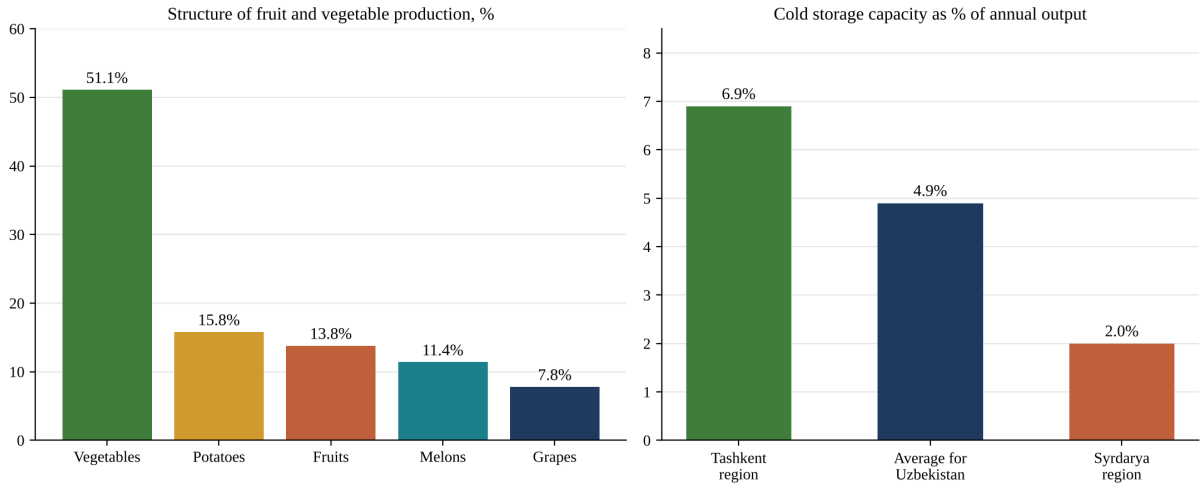


Figure 1. Structure of fruit and vegetable production and cold storage capacity as a share of output by region

Source: compiled and calculated by the author based on [11–13].

To assess the scale of the problem, the author compared the existing capacity with the capacity required to store three quarters of the export volume (Figure 2). To store 75% of 2024 exports (about 2.04 million tonnes), about 1.53 million tonnes of capacity would be needed; for 2025 exports (2.2 million tonnes), about 1.65 million tonnes. The resulting gap is therefore about 0.5 million tonnes, and it is growing faster than new facilities are commissioned. Even the government target of 1.9 million tonnes by 2027 would cover only a small part of total output, which means that capacity growth must be accompanied by much better use of existing facilities, i.e. by higher turnover, accurate demand planning and reduced storage time.

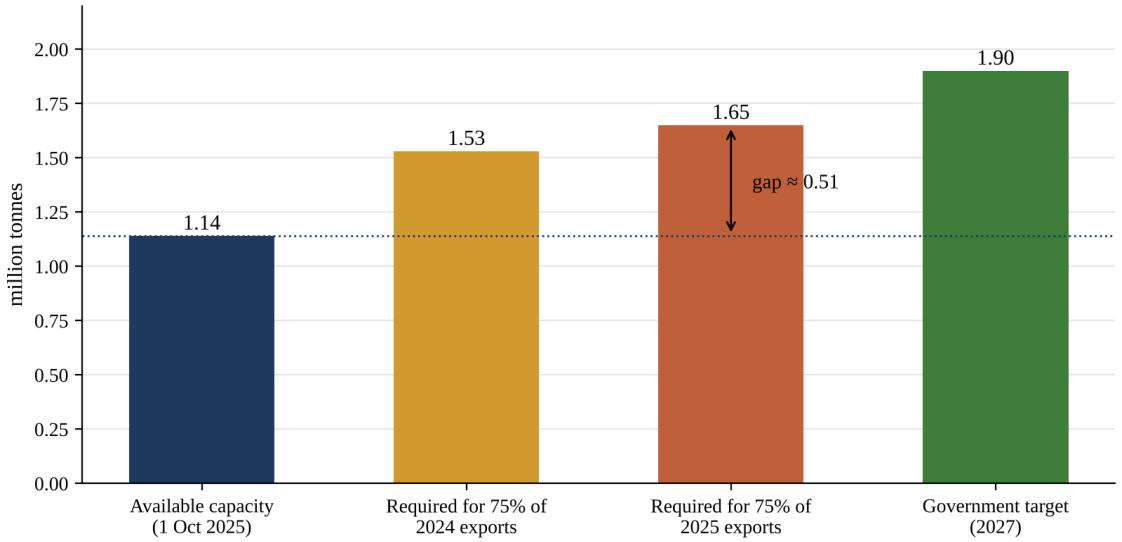


Figure 2. Existing and required cold storage capacity, million tonnes

Source: calculated by the author based on [11; 12].

The economic importance of reducing losses can be illustrated by a simple estimate. If losses were reduced by 5–7.5 percentage points of an annual output of about 23 million tonnes, an additional 1.15–1.7 million tonnes of produce would reach the market. At the average export unit value of about USD 955 per tonne in 2025 [11], the potential value would be roughly USD 1.1–1.6 billion a year. This is an indicative upper estimate, since not all saved products would be exported; nevertheless, it shows that loss reduction is comparable in scale to the annual growth of the whole sector's exports.

Based on the reviewed theory and the analysis, an integrated model of digital and logistics-based management of a fruit and vegetable enterprise was developed (Figure 3). The model has three levels. The upper level is an integrated digital platform of the enterprise (ERP, data analytics and management dashboards). The middle level consists of four digital modules: demand forecasting and order management; IoT monitoring of temperature and humidity; a warehouse management system (WMS) operating on the FEFO principle; and product traceability using QR codes and, where justified, blockchain. The lower level is the physical logistics flow of the enterprise, divided into five stages, from procurement on farms to sales to retail chains, export buyers and e-commerce channels.

The key feature of the model is the two-way exchange of data in real time between the digital modules and the physical flow. Sensors in chambers and refrigerated trucks transmit temperature and humidity data to the platform; on this basis the WMS estimates the remaining shelf life of each batch and assigns dispatch according to FEFO rather than FIFO, as proposed by R. Jedermann and co-authors [10]. The demand forecasting module uses sales history, orders from retail chains and seasonal price data to plan procurement and storage volumes, which reduces both shortages and overstocking. The traceability module links each batch to the farm, harvest date, storage conditions and quality certificates, which is required by retail chains and importers and simplifies recalls [6].

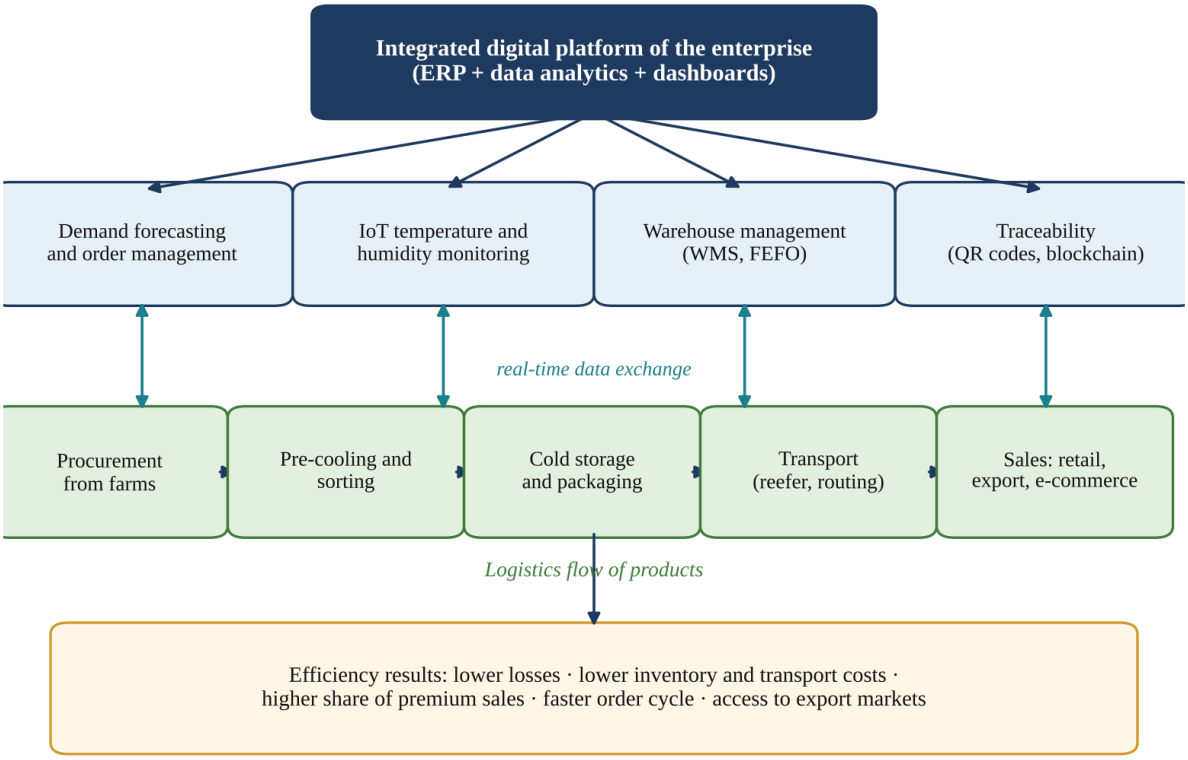


Figure 3. Integrated model of digital and logistics-based management of a fruit and vegetable enterprise
Source: developed by the author based on [2; 6; 9; 10].

The content of the mechanisms and the indicators for evaluating their efficiency are presented in Table 2.

Table 2

Digital and logistics-based management mechanisms and key performance indicators of a fruit and vegetable enterprise

Mechanism	Main instruments	Key performance indicators
Demand-driven planning	demand forecasting, contract procurement, sales and operations planning	forecast accuracy, %; stock-out rate, %; share of contracted procurement, %
Cold chain management	pre-cooling within hours of harvest, IoT sensors, alarms, reefer transport	share of batches within the temperature range, %; post-harvest losses, %
Warehouse management	WMS, FEFO dispatch, barcode/QR labelling, cell addressing	inventory turnover, days; capacity utilization, %; order picking time, h
Transport optimization	route planning software, load consolidation, GPS tracking	cost per tonne-km; vehicle load factor, %; on-time delivery, %
Traceability and quality	batch identification, digital certificates, blockchain records	share of traceable batches, %; claims and returns, %
Integrated management	ERP, dashboards, data analytics	order-to-delivery cycle, days; logistics cost as % of revenue; margin, %

Source: developed by the author based on [2; 3; 6–10].

To illustrate the expected effect, a conditional calculation was made for an enterprise that procures and sells 10,000 tonnes of fruit and vegetables a year (Table 3). It is assumed that the introduction of pre-cooling, IoT monitoring and FEFO-based warehouse management reduces losses from 25% to 12%, and that the average selling price is USD 500 per tonne. The values are illustrative and should be adjusted to the data of a particular enterprise.

Table 3

Conditional calculation of the effect of digital and logistics mechanisms for an enterprise handling 10,000 tonnes per year

Indicator	Before	After	Change
Post-harvest losses, %	25	12	−13 p.p.
Products sold, t	7,500	8,800	+1,300
Revenue at USD 500/t, thousand USD	3,750	4,400	+650
Annual costs of digital systems and additional cooling, thousand USD (assumed)	—	150	+150
Net annual effect, thousand USD	—	—	≈ +500

Source: author's conditional calculation; the assumptions are given in the text.

Even with conservative assumptions, the additional revenue from reduced losses substantially exceeds the costs of digital systems and additional cooling. In practice the effect would be higher, because it would also include lower inventory and transport costs, a higher share of premium-grade sales and access to export markets that require traceability. The main barriers are the high initial investment, the lack of qualified personnel and unstable power supply in rural areas; therefore, implementation should be phased, starting with low-cost solutions such as temperature data loggers, barcode labelling and a cloud-based WMS.

Conclusions and recommendations

The study leads to the following conclusions. First, despite rapid export growth, fruit and vegetable enterprises in Uzbekistan still lose 20–30% of produce after harvest, and the main cause is logistical rather than agronomic. Second, the existing cold storage capacity (1.14 million tonnes in 2,011 facilities) covers only about 4.9% of output, is unevenly distributed across regions, and is short of the export-related need by about 0.5 million tonnes. Third, international experience shows that digital tools such as IoT monitoring, FEFO-based warehouse management and traceability are most effective when they are integrated with the physical logistics system of the enterprise.

To improve the efficiency of fruit and vegetable enterprises, the following measures are recommended: (1) to adopt the integrated model of digital and logistics-based management, combining an ERP platform with demand forecasting, IoT, WMS and traceability modules; (2) to organize pre-cooling and sorting at collection points close to farms and to switch from FIFO to FEFO dispatch; (3) to use route optimization and load consolidation to reduce transport costs; (4) to implement the KPI system proposed in Table 2 and monitor it through management dashboards; (5) at the state level, to extend preferential leasing and credit for cold storage and digital equipment, with priority to regions with the lowest storage coverage, and to train logistics and IT specialists for the agri-food sector. Implementing these mechanisms will reduce losses, make better use of existing storage capacity and raise the competitiveness of enterprises in domestic and export markets.

References

1. Decree of the President of the Republic of Uzbekistan No. PF-5853 ”On approval of the Strategy for the Development of Agriculture of the Republic of Uzbekistan for 2020–2030”, 23 October 2019 // lex.uz.

2. Christopher M. Logistics & Supply Chain Management. 5th ed. – Harlow: Pearson, 2016.

3. Ballou R.H. Business Logistics/Supply Chain Management. 5th ed. – Upper Saddle River: Pearson Prentice Hall, 2004.

4. Kader A.A. Increasing food availability by reducing postharvest losses of fresh produce // Acta Horticulturae. – 2005. – No. 682. – P. 2169–2176.

5. FAO. The State of Food and Agriculture 2019. Moving Forward on Food Loss and Waste Reduction. – Rome: FAO, 2019.

6. Aung M.M., Chang Y.S. Traceability in a food supply chain: Safety and quality perspectives // Food Control. – 2014. – Vol. 39. – P. 172–184.

7. Kamilaris A., Fonts A., Prenafeta-Boldú F.X. The rise of blockchain technology in agriculture and food supply chains // Trends in Food Science & Technology. – 2019. – Vol. 91. – P. 640–652.

8. Wolfert S., Ge L., Verdouw C., Bogaardt M.-J. Big Data in Smart Farming – A review // Agricultural Systems. – 2017. – Vol. 153. – P. 69–80.

9. Verdouw C.N., Wolfert J., Beulens A.J.M., Rialland A. Virtualization of food supply chains with the internet of things // Journal of Food Engineering. – 2016. – Vol. 176. – P. 128–136.

10. Jedermann R., Nicometo M., Uysal I., Lang W. Reducing food losses by intelligent food logistics // Philosophical Transactions of the Royal Society A. – 2014. – Vol. 372. – Article 20130302.

11. Statistics Agency under the President of the Republic of Uzbekistan. Uzbekistan exported USD 2.1 billion worth of fruits and vegetables // stat.uz. – 2026.

12. Cold storage capacity in Uzbekistan: number of facilities and regional distribution // UzDaily.uz. – 2025.

13. International Trade Administration (U.S. Department of Commerce). Uzbekistan – Country Commercial Guide: Agriculture and Food Processing // trade.gov. – 2025.