Implementation of Innovative Technologies in Inventory Management in Cotton-Textile Clusters

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Abstract

The article analyzes the application of innovative technologies in inventory management within cotton-textile clusters (CTCs). The study highlights the significance of efficient inventory planning for ensuring uninterrupted production processes, optimizing costs, and meeting market demand. The work examines domestic and international experiences in inventory management, as well as the impact of digitalization, monitoring systems, and modern logistics on production efficiency. The research also presents forecasts under inertial and innovative development scenarios, emphasizing the potential growth of cotton yield, production volumes, and exports by 2030. The findings provide practical recommendations for enhancing the competitiveness of Uzbekistan's cotton-textile industry through the introduction of advanced technologies in inventory and resource management.

Keywords: Cotton-textile clusters, inventory management, innovative technologies, production efficiency, logistics, forecasting, Uzbekistan.

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1. Introduction

The textile industry is one of the largest sectors in the world, providing millions of jobs. The development of the textile industry contributes significantly to the gross domestic product (GDP) of many countries and supports the growth of international trade. In recent years, the market size of the textile industry has grown substantially. According to World Bank forecasts, it is expected to grow from USD 640.43 billion in 2024 to USD 696.16 billion in 2025, with an average annual growth rate of 8.7% [1].

The textile industry is becoming increasingly globalized, which requires companies in different countries to consider logistics chains, delivery times, and political risks, directly affecting inventory management.

In Uzbekistan, significant economic reforms are currently being implemented to develop industrial sectors. In particular, the following regulatory documents and presidential decrees play an important role in supporting the textile industry and cotton-textile clusters:

PF-2 dated January 10, 2023, "On measures to support the activities of cotton-textile clusters, fundamentally reform the textile and sewing-knitting industry, and further increase the export potential of the sector";

PF-6079 dated October 5, 2020, "On approval of the 'Digital Uzbekistan-2030' Strategy and measures for its effective implementation";

PF-23 dated January 26, 2023, "On additional measures to further support cotton raw material producers".

The effective implementation of these tasks contributes to the improvement of the evaluation and development of industrial sectors in Uzbekistan, particularly the textile industry.

Analysis of Literature Related to the Topic

We consider the opinions of some local and foreign scholars regarding the peculiarities of inventory management. In the works of V.P. Kodatsky, it is stated that "inventory management should be considered as part of the general management system of an enterprise and is an integral part of the production and sales process" [3].

According to A.Sh. Akhmadov, who studied the production strategies of industrial enterprises, "there is a conflict of objectives regarding inventories when creating stocks at an enterprise. The financial department always prefers to maintain low inventory levels to improve sales, while production requires sufficient stocks to ensure a smooth workload" [4]. This conflict of interests should generally be resolved in favor of the enterprise, ensuring financial stability and preventing excessive working capital from being frozen in surplus inventories.

The costs of purchasing and maintaining inventories are often comparable to the value of the inventories themselves, and this should be avoided, as it prolongs the inventory turnover period. This issue should remain the focus of managers seeking to minimize the funds invested in inventory while maintaining the continuity of the production process.

Planning the procurement and consumption of raw materials and supplies relies on the rational planning and control of financial, informational, and material flows to ensure maximum effective use of enterprise resources.

N.A. Khromikh emphasizes that "effective management of material and technical resources cannot be implemented without careful analysis and optimization of their use. All production enterprises must pay attention to the state of working capital, including material stocks, work-in-progress, and finished products" [5].

Discussing the diversity of inventories, N.M. Mominova notes that "different types of inventories arising in various situations due to different reasons are united by a common problem. This problem involves optimizing order quantities and time intervals between related supplies and determining the economic parameters of inventory management models" [6]. From this, it can be concluded that the most important parameters of inventory management models are determined by the intensity of demand for the materials and resources constituting the inventory.

Currently, there is a trend toward transitioning from managing inventories separately to managing business processes as a whole. O.N. Zueva describes a logistics business process as "an interconnected set of operations and functions transforming company resources to achieve results determined by the firm's logistics strategy or consumer demand through the management of goods and related flows" [7].

The main goal of a logistics business process is to ensure timely and efficient delivery of goods from the producer to the final consumer. It starts with supply planning and includes procurement of raw materials and supplies, placement in the enterprise warehouse, internal transport between production units, monitoring of production and warehouse stocks, and calculation of necessary replenishment levels.

V.I. Malyuk writes that "cost optimization is the main objective in designing production sites, supply chains, and logistics infrastructure. For manufacturing, this often means concentrating capacities in one or a few low-cost countries in large enterprises, which is characteristic of the textile industry, where excess stocks and capacities are equivalent to losses" [8].

Analyzing foreign experience in managing production inventories in cotton-textile clusters is considered appropriate. The main elements of this experience, based on scholars' views, are examined in the main part of this article.

Analysis and Results

The analysis of the efficiency of production inventories in cotton–textile clusters conducted earlier within the framework of this study revealed the presence of inefficient use of raw materials, a significant volume of work-in-progress inventories, and a considerable amount of excess inventories.

In order to effectively manage production inventories, a comprehensive analysis of initial data is required. For this purpose, a model for the analysis and forecasting of production inventories is used. It is recommended to use lean manufacturing technologies to improve production inventory management models (by reducing losses and optimizing business processes).

The application of a lean manufacturing model involves identifying and eliminating losses in the supply chain (including excess inventories, waiting times, overproduction, defects, and inefficient operations), as well as optimizing supply and storage processes by achieving maximum simplicity and responsiveness.

Table 1 presents business processes in CTC enterprises characterized by inefficient use of inventories and their improvement through the application of lean manufacturing methods.

Table 1

Improving Business Processes in CTC Enterprises through Lean Manufacturing Methods

Shortcomings of existing business processes	Business process improvement measures	Description of corrective actions
Excessive transportation of goods within the warehouse	Changing inventory placement zones in the warehouse to shorten product movement trajectories	– Planning the layout of departments: placing core warehouse operations in the center and auxiliary operations at the periphery; – Locating core warehouse operation units as close to each other as possible; – Strict separation of inbound and outbound material flows.
Excess operations that do not create value	Eliminating excess inventories	– Maintaining minimal inventory levels for low-rotation items in picking zones; – Recording all employee reports regarding disruptions and inconveniences; – Performing tasks accurately and on time (avoiding premature execution and delays).
Equipment downtime	Material incentives for optimal picking within minimal time	– Applying the most effective staff motivation methods (using piece-rate or piece-rate bonus payment systems instead of time-based wages).

Improving warehouse logistics business processes through the use of lean manufacturing methods contributes to a reduction in inventory volumes in warehouses and an increase in inventory turnover.

From a logistics perspective, the main advantage is the reduction of inventories throughout the supply chain, which in turn leads to lower costs. Significant results in reducing total supply chain costs can be achieved by optimizing inventory levels across the chain.

Let us consider the application of logistics technologies that contribute to increasing the efficiency of production inventory management in CTC enterprises.

CPFR (Collaborative Planning, Forecasting, and Replenishment) represents a powerful tool for improving interaction among supply chain participants through data sharing, performance analysis, discussion of deviations, and the establishment of systems for further process optimization.

Sales and Operations Planning (S&OP) is a technology that enables CTC enterprises to align logistics and marketing strategies with operational capabilities. The S&OP approach helps create a unified operations management center that integrates all departments of the enterprise. VMI (Vendor-Managed Inventory) is a technology for managing customer inventories that embodies a supply chain management strategy, in which the supplier assumes responsibility for managing inventories at the customer's site. The effectiveness of VMI depends on the efficiency of information exchange between the supplier and the customer, including data on sales and inventory levels, which are necessary for making management decisions.

VMI serves as a powerful tool in supply chain management that can provide significant advantages for both suppliers and customers. For CTC enterprises, the adaptability of VMI depends on the level of integration among enterprises within a single cluster.

Thus, each technology reviewed in Table 4.2 has a distinct impact on inventory reduction. Vendor-Managed Inventory – VMI Assigns responsibility for managing inventories to the supplier, the entity best positioned to control stock levels. Enables collaboration between supplier and customer for demand forecasting and supply planning, reducing the risk of stockouts or excess inventories.

The advantages of using the reviewed logistics technologies in CTC enterprises are presented in Table 2

Table 2

Technologies Contributing to Inventory Reduction in the Supply Chains of CTC Enterprises

Technology Name	Technology Description	Impact on Inventory Reduction
Collaborative Planning, Forecasting, and Replenishment – CPFR	Integrates key marketing and logistics business processes within the existing supply chain, coordinating the actions of counterparties.	Improves logistics business processes, helping CTC enterprises reduce inventory volumes and manage them more efficiently.
Sales and Operations Planning – S&OP	Links the enterprise's strategic plans and business plan with operational processes through order entry and purchase schedules.	Reduces storage time in warehouses as orders are formed according to current and expected demand, optimizing inventory levels.

Table 3: Advantages of Implementing CPFR, S&OP, and VMI Logistics Technologies in CTC Enterprises

Technology	Inventory Reduction	Increase in Sales Volume	Cost Reduction	Improved Forecast Accuracy	Increased Supply Chain Flexibility
Collaborative Planning, Forecasting, and Replenishment – CPFR	+	+	+	+	+

Technology	Inventory Reduction	Increase in Sales Volume	Cost Reduction	Improved Forecast Accuracy	Increased Supply Chain Flexibility
Sales and Operations Planning – S&OP	+		+		+
Vendor-Managed Inventory – VMI		+		+	

Analysis of Table3 indicates that CPFR technology is the most effective logistics technology for CTC enterprises. However, the application of other technologies also has a positive effect by reducing uncertainty and risk levels inherent in the operations of CTC enterprises. Successful implementation and effective use of the reviewed logistics technologies are not possible without digitalizing the supply chain.

To achieve optimal inventory management, it is necessary to address tasks related to production scheduling optimization and inventory control. We will examine the methodology proposed by the author for jointly optimizing the production schedule and raw material inventories. In the production scheduling calculations of a CTC enterprise, criteria for minimizing equipment downtime are applied, taking into account the following constraints based on the planned production volume:

The production volume of each product assortment is equal to the order quantity;

The labor intensity of each production operation is greater than zero;

The available working time for each operation is limited.

Additionally, in the production scheduling calculations, the criterion of maximizing marginal profit is applied without constraints on raw material availability.

$$F(n_{ii}) = \sum_{i=1}^{n} W_{ii} * n_{ii}$$

R – PTK korxonalaridagi har bir kasb bo‘yicha ishlovchilar soni; Here:

R – the number of employees in each occupation at a CTC enterprise;

t – the duration of each technological operation;

i – the index of technological operations, ranging from 1 to N;

T – the total labor time available.

A larger number of employees allows for more efficient task allocation and better responsiveness to changes in the production schedule. To ensure competitiveness and efficiency, CTC enterprises must find an optimal balance between the number of employees, the production schedule, and inventory levels. In the production scheduling calculations of a CTC enterprise, criteria for minimizing equipment downtime are applied, taking into account the following constraints based on the planned production volume:

The production volume of each product assortment is equal to the order quantity;

The labor intensity of each production operation is greater than zero;

The available working time for each operation is limited.

Additionally, in the production scheduling calculations, the criterion of maximizing marginal profit is applied without constraints on raw material availability.

Subsequently, it is necessary to solve the transportation problem based on the criterion of minimizing costs for the purchase, delivery, and storage of the required raw materials. In market conditions, the availability of raw material resources is limited, which requires determining the optimal ratio between profit, cost, and resource efficiency. Optimization models with different characteristics often lead to linear programming problems, allowing the identification of a unique optimal combination of variables within a system of constraints.

Using linear programming, the production schedule and inventory optimization model for Alyorteks LLC was calculated. For each year in the model, parameters describing the interrelationship between the number of employees, production volume, costs for raw materials and supplies, and inventory profitability were compared, and the most optimal set was identified. To solve the linear programming problem, an additive criterion of optimality was used according to the formula:

$$F(n_{ii}) = \sum_{i=1}^{n} W_{ii} * n_{ii}$$

where $\sum_{n} W_j = 1, n_{ii}$ denotes the value of the local criterion, and W_j represents the importance of the j-th sub-criterion.

The calculations yielded the additive optimality criterion for each parameter set. According to the results (Appendix 2), Variant 1 for 2025 (F1) was selected as it corresponds to the highest value of the additive optimality criterion. The most optimal parameter set for Alyorteks LLC for aligning the production schedule and inventories is: number of employees – 351; production volume – 310.0 billion UZS; raw materials and supplies costs – 125.0 billion UZS; inventory profitability – 50% .

Similarly, linear programming calculations were carried out for Boyovut Techno Cluster LLC, resulting in the optimal parameter set: number of employees – 522; production volume – 150.1 billion UZS; raw materials and supplies costs – 330.0 billion UZS; inventory profitability – 29% .

For TST Agro Cluster LLC, linear programming was also applied. The optimal parameter set for aligning the production schedule and inventories is: number of employees – 7,690; production volume – 599.0 billion UZS; raw materials and supplies costs – 1,471.5 billion UZS; inventory profitability – 35%.

Thus, the following conclusions can be drawn regarding the improvement of production inventory management models in cotton–textile clusters:

The use of lean manufacturing technologies is recommended to reduce losses and optimize business processes.

The implementation of logistics technologies that improve production inventory management efficiency in CTC enterprises is proposed: Collaborative Planning, Forecasting, and Replenishment (CPFR); Sales and Operations Planning (S&OP); Vendor-Managed Inventory (VMI).

Successful implementation and effective use of these logistics technologies are impossible without digitalizing the supply chain.

To achieve optimal inventory management, it is necessary to solve tasks related to both production scheduling optimization and inventory control.

Linear programming methods were applied to calculate the production schedules and inventory optimization models for Alyorteks LLC, Boyovut Techno Cluster LLC, and TST Agro Cluster LLC.

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