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MODERN INFORMATION TECHNOLOGIES AND THEIR APPLICATION IN INVENTORY MANAGEMENT

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Abstract: *Inventory plays a central role in the supply chain, connecting every stage–from procurement to sales. Efficient inventory management contributes to cost reduction, increased profitability, and strengthening of competitive advantage [1, 23]. Modern enterprises face challenges such as globalization, volatile demand, and the need for rapid response to market changes. For this reason, digitalization of inventory management processes has become a key prerequisite for competitiveness and sustainable business operations.*

Inventory management represents a crucial element of efficient business performance. Effective inventory control enables organizations to reduce costs, increase liquidity, and improve customer satisfaction. The aim of this paper is to present traditional and modern models of inventory management, with special emphasis on the application of information technology and artificial intelligence. The general objective is to examine and demonstrate the role of information technologies in improving inventory management processes and their influence on business efficiency-reducing total holding and ordering costs; increasing speed and reliability of decision-making; ensuring higher data accuracy and better control over stock movement.

The subject of this research is the analysis of the significance and impact of information technologies on planning, control, and optimization processes of inventory across enterprises of different industries. In today's business environment, information technology (IT) plays a key role in enhancing inventory management and improving supply chain efficiency. The paper also presents a Python-based software solution for calculating Economic Order Quantity (EOQ).

This research will utilize a combination of qualitative and quantitative methods. For data processing and analysis, statistical methods (descriptive statistics, correlation analysis, regression models) will be applied using software tools such as Excel or SPSS.

Understanding the purpose, categories, and inventory management systems enables companies to achieve an optimal balance between product availability and holding costs. Contemporary practice increasingly relies on digitalization and forecasting models that enhance decision-making and make the supply chain more resilient and efficient.

Keywords: *information technologies, artificial intelligence, digitalization, supply chain, inventory, economic order quantity*

INTRODUCTION

Inventory refers to temporarily allocated quantities of materials, energy, or information taken out of the production or consumption process to ensure business continuity and timely response to market needs. It represents a buffer between the input and output flows of goods, arising when there is a difference in time or quantity between procurement and consumption. Inventory management involves decisions regarding required quantities, stock formation methods, control, and replenishment, while taking into consideration all factors that influence inventory movement. It is one of the key activities within production management, since inventory requires substantial capital and affects production, marketing, and finance. Different types of materials and goods may be held as inventory: raw materials and semi-finished products, finished products, tools and spare parts, consumables, and technical waste [5,23].

Depending on the criteria, inventory can be classified in several ways. The most common categories are:

a) **According to their function in the business process:**
- Production inventory – raw materials and supplies required for the manufacturing process.
- Auxiliary inventory – spare parts, tools, packaging, and other elements not directly included in the product but necessary for system functioning.
- Commercial inventory – finished products intended for sale to end customers.
- Inventory in transit – goods that are being transported between suppliers, producers, and consumers.

b) **According to the stage of processing:**
- Raw material and component inventory – procured materials ready for production.
- Semi-finished goods inventory – partially processed products awaiting further manufacturing.
- Finished goods inventory – final products ready for sale.

c) **According to purpose and intent:**
- Operational (working) inventory – ensures continuous production flow.
- Safety inventory – serves as a reserve for unforeseen situations, such as delivery delays or sudden demand spikes.
- Seasonal inventory – formed during periods of increased demand (e.g., holidays).
- Speculative inventory – created when price increases or material shortages are anticipated.

Such classification enables companies to plan their needs more accurately and allocate capital more efficiently.

Forecasting is a key tool in inventory planning because it allows prediction of future demand. Based on historical data, seasonal patterns, and market trends, quantitative and qualitative forecasts are generated to support purchasing and production decisions. The most widely used methods include moving averages, exponential smoothing, and regression models. Accurate forecasting reduces the risk of overstocking or understocking and has a direct impact on company profitability.

In the modern business environment, information technology (IT) plays a crucial role in improving inventory management processes and increasing supply chain efficiency. Rapid development of digital tools, integrated software solutions, and real-time data tracking systems has enabled organizations to reduce costs, connect different operational stages, and make decisions based on precise information. Efficient inventory management today is not possible without the implementation of modern IT solutions such as ERP (Enterprise Resource Planning), WMS (Warehouse Management System), MRP (Material Requirements Planning), as well as various demand forecasting and data analysis tools. Their application contributes to reducing delays, improving delivery accuracy, lowering storage costs, and increasing transparency throughout the supply chain.

1. LITERATURE REVIEW

Inventory management has long been recognized as a critical component of operations and supply chain management. Classical models such as Economic Order Quantity (EOQ), safety stock formulas, and reorder point systems focused primarily on balancing ordering and holding costs under relatively stable and predictable conditions (Harris, 1913; Zipkin, 2000). With the growth of globalization, shorter product life cycles, and increased demand volatility, these traditional approaches have been increasingly complemented and transformed by modern information technologies that enable faster, data-driven and more collaborative decision-making across the supply chain.

1.1. From Traditional to Technology-Enabled Inventory Management

In the traditional view, inventory decisions were often based on historical demand, manual records and periodic reviews. This approach was prone to delays, errors and the bullwhip effect, where small fluctuations in demand at the retail level amplify upstream in the supply chain (Lee, Padmanabhan & Whang, 1997). The emergence of integrated information systems, especially Material Requirements Planning (MRP) and later Enterprise Resource Planning (ERP), enabled companies to connect procurement, production, warehousing and sales in a unified database, thus improving visibility and coordination of inventory flows (Monk & Wagner, 2013).

Subsequent generations of systems extended this logic to the entire supply chain. Supply Chain Management (SCM) systems and Advanced Planning and Scheduling (APS) tools support multi-echelon inventory optimization, collaborative planning and real-time information sharing between suppliers, manufacturers, distributors and retailers (Stadtler, 2015). These platforms provide the digital backbone upon which more advanced technologies – such as RFID, IoT, big data analytics and artificial intelligence – are now being layered.

1.2. Core Information Technologies in Inventory Management

A number of modern information technologies have reshaped how firms track, control and optimize inventory:

- **Barcoding and RFID.** Barcodes and, more recently, Radio Frequency Identification (RFID) tags have fundamentally improved the accuracy and speed of inventory tracking. RFID, in particular, enables automatic, non-line-of-sight identification of items, leading to reduced counting errors, lower labor costs and improved stock visibility (Asif & Mandviwalla, 2005). Empirical studies show that RFID adoption can significantly reduce out-of-stock situations and shrinkage, especially in retail and healthcare supply chains (Wamba et al., 2008).
- **Warehouse Management Systems (WMS).** WMS solutions provide real-time information on stock locations, quantities and movements within the warehouse, supporting

activities such as put-away, picking, cycle counting and replenishment. Integration of WMS with ERP and transportation systems improves overall logistics performance, reduces lead times and enables more accurate inventory records (Faber, De Koster & Smidts, 2013).

- **Cloud-based platforms and digital integration.** Cloud computing has facilitated the development of scalable, pay-as-you-go inventory and supply chain platforms that are particularly attractive for small and medium-sized enterprises. Cloud-based inventory systems enable multi-location visibility, easier integration with e-commerce channels and collaboration with external partners, reducing the need for heavy upfront IT investments (Marston et al., 2011).
- **Internet of Things (IoT).** IoT devices—such as smart shelves, sensors and connected forklifts—collect real-time data about inventory levels, storage conditions (e.g., temperature, humidity) and equipment utilization. This data improves the accuracy of inventory records, helps prevent spoilage or damage, and supports predictive maintenance of logistics equipment (Ben-Daya, Hassini & Bahroun, 2019).

1.3. BIG DATA ANALYTICS AND ARTIFICIAL INTELLIGENCE IN INVENTORY MANAGEMENT

The proliferation of digital data has created new opportunities to enhance inventory decisions with advanced analytics and artificial intelligence (AI). Big data sources include point-of-sale (POS) systems, loyalty programs, web traffic, social media, supplier performance data and sensor outputs across the supply chain [13, 14].

Demand forecasting and replenishment.

Machine learning models—such as gradient boosting, random forests, and deep learning architectures—can capture non-linear relationships and complex seasonality patterns in demand, often outperforming traditional time-series methods in volatile environments (Carbonneau, Laframboise & Vahidov, 2008). These models enable more accurate demand forecasts, which are crucial for setting safety stocks, reorder points and replenishment schedules.

Optimization and decision support.

AI-based optimization and reinforcement learning approaches are increasingly used to determine optimal order quantities, allocation decisions and dynamic pricing that jointly influence inventory levels (Kumar et al., 2016). Decision support systems integrate these models with real-time data from ERP, WMS and IoT, providing managers with recommended actions or triggering automated replenishment in vendor-managed inventory (VMI) and consignment stock arrangements.

Exception management and anomaly detection.

AI techniques are also applied to detect anomalies and risks in inventory data—such as unexpected demand spikes, data entry errors or potential stock-outs—allowing proactive intervention instead of reactive problem-solving.

1.4. IMPACT OF MODERN IT ON INVENTORY PERFORMANCE

Numerous studies indicate that the adoption of modern information technologies positively affects inventory performance and broader business outcomes. Improved information quality and visibility lead to reduced safety stock, lower overall inventory levels, shorter order cycles and fewer stock-outs (Chopra & Meindl, 2016). RFID and real-time tracking have been linked to higher inventory accuracy and improved product availability in retail and manufacturing environments (Wamba et al., 2008).

Integration of ERP, WMS and advanced analytics supports better coordination between procurement, production and distribution, which in turn improves service levels and customer satisfaction while reducing working capital tied up in inventory (Gunasekaran & Ngai, 2004). At the same time, digital tools enable scenario analysis and "what-if" simulations, helping managers evaluate the impact of parameter changes—such as lead times, order frequencies or demand variability—on total inventory cost and service levels.

1.5. Challenges and Limitations in the Adoption of Modern IT

Despite the demonstrated benefits, literature also emphasizes several challenges related to the adoption and effective use of modern IT in inventory management. High initial investment costs, integration issues with legacy systems, data quality problems and resistance to organizational change can limit the realized benefits (Gunasekaran & Ngai, 2004).

In addition, the successful use of AI and analytics requires appropriate data governance, skilled personnel and a clear understanding of model limitations. Over-reliance on algorithmic outputs without managerial judgement may lead to suboptimal or risky decisions, especially in situations of structural market change or unprecedented events (e.g., pandemics, geopolitical shocks).

1.6. Research Gap

While previous research has thoroughly examined individual technologies—such as ERP, RFID or specific machine learning models—there is a growing need for integrated studies that analyze how combinations of modern information technologies jointly affect inventory performance across different industries and firm sizes. Furthermore, there is limited empirical work on how AI-driven decision-support tools are actually embedded into everyday inventory management processes and how they change the roles and competencies of managers and planners.

This paper contributes to the existing literature by providing a structured overview of traditional and modern inventory management models, analyzing the role of information technologies and artificial intelligence in improving key inventory processes, and illustrating these concepts through a Python-based software solution for Economic Order Quantity (EOQ) calculation.

2. THE ROLE OF INVENTORY IN THE SUPPLY CHAIN

Inventory plays a crucial role in the functioning of the supply chain, as it connects all its stages—from suppliers to end consumers. Its primary purpose is to maintain balance between supply and demand, since these two flows rarely coincide over time. The main functions of inventory within supply chains include [11, 17]:

- **Buffer function:** inventory softens the imbalance between production and consumption, ensuring a continuous process.
- **Continuity function:** prevents production delays due to late procurement.
- **Price stabilization function:** enables companies to respond to market price fluctuations and avoid losses.
- **Service function:** increases customer service level through faster delivery.

Efficient inventory management contributes to reducing total logistics costs, increasing liquidity, and strengthening a company's competitive advantage. In modern business systems, inventory forms a part of a broader concept—Supply Chain Management (SCM). Through digitalization and use of advanced information systems (ERP, MRP, WMS), companies can monitor inventory levels in real time and automatically plan procurement and distribution. This reduces storage costs, waiting times, and the risk of product obsolescence.

Finance departments aim for low inventory levels to preserve capital, marketing seeks higher stock to increase sales and responsiveness, while production requires optimal stock to maintain an uninterrupted workflow. Therefore, inventory management must balance these opposing goals.

There are three basic material management models:

- **Push model** – based on forecasts,
- **Pull model** – based on actual customer demand,
- **Hybrid model** – a combination of both, depending on supply chain structure.

Inventory provides flexibility, reduces risk, and increases the ability of a company to respond to demand fluctuations. However, excessive inventory ties up capital, occupies storage space, and is prone to spoilage, obsolescence, and high storage costs. Low inventory reduces costs but increases the risk of shortages and inability to meet demand. The main reasons for maintaining inventory are:

1. Protection against uncertainties (safety stock);
2. Achieving economical production and purchase cycles (cycle stock);
3. Preparation for expected price, demand, or supply fluctuations;
4. Ensuring material availability during transportation between process stages.

The basic function of inventory is to separate different phases of production and consumption: raw materials separate suppliers from production, work-in-process separates production stages, and finished goods separate manufacturers from customers.

3. IMPORTANCE AND TYPES OF INVENTORY IN THE SUPPLY CHAIN

Depending on criteria, inventory can be classified in several ways. The most common divisions are:

a) **According to function in the business process:**
  - Production inventory – raw materials and components necessary for manufacturing.
  - Auxiliary inventory – spare parts, tools, packaging, and elements that do not enter the final product but enable system operation.
  - Commercial inventory – finished goods intended for sale to end customers.
  - Inventory in transit – goods currently being transported between suppliers, manufacturers, and final users.

b) **According to point of origin**:
  - Raw material inventory – procured components ready for processing.
  - Semi-finished goods inventory – partially processed products awaiting further production.
  - Finished goods inventory – completed products ready for sale.

c) **According to purpose and intent**:
  - Operational (working) inventory – ensures continuous production processes.
  - Safety inventory – reserve stock for unexpected events such as delivery delays or sudden demand spikes.
  - Seasonal inventory – created in periods of increased demand (e.g., holidays).
  - Speculative inventory – created when price increases or shortages are expected.

This classification enables more efficient inventory planning, control, and optimization. Inventory ensures continuous business operations between procurement, production, and sales, reducing risks of supply disruptions.

As a buffer between unpredictable supply and demand flows, inventory allows companies to react quickly to customer needs, avoid production interruptions, and benefit from favorable market conditions such as seasonal discounts or lower procurement prices. Although maintaining inventory incurs costs, it improves system reliability and customer satisfaction, which strengthens competitive advantage in the long term.

With digitalization and implementation of systems such as ERP, MRP, and WMS, businesses can track inventory levels in real time and automate replenishment processes, reducing storage cost, waiting time, and product aging risk.

4. CLASSIC INVENTORY PLANNING MODELS IN THE SUPPLY CHAIN

Optimal inventory represents the quantity of materials or goods that fully satisfies consumption needs with minimum total cost. The goal is to maintain enough inventory to prevent shortages and ensure continuous operations, while not tying up more capital than necessary. The optimal level of inventory is influenced by factors such as demand dynamics, delivery lead time, storage costs, and safety stock policies.

Classic inventory management models are the foundation of modern logistics and procurement systems. Their primary purpose is to optimize order quantities, reduce storage and ordering costs, and ensure availability of materials or goods when needed. In practice, the most frequently used models are EOQ, ABC/XYZ classification, Just-in-Time (JIT), and integrated MRP/ERP systems. These approaches help organizations balance supply and demand, lower operational costs, and increase supply chain efficiency.

4.1. EOQ MODEL (ECONOMIC ORDER QUANTITY)

In operational practice, optimal inventory levels are determined through mathematical models—most commonly using the EOQ model, which balances ordering cost and holding cost.

The **Economic Order Quantity (EOQ)** is the order size that minimizes total inventory cost. Inventory-related costs include:

- Ordering costs (transportation, administration, purchasing);
- Holding costs (storage, depreciation, insurance);
- Shortage costs (lost sales and customer dissatisfaction).

EOQ helps companies determine the optimal order volume where the sum of ordering and holding costs is the lowest. The goal is to find an order quantity that minimizes total inventory expenditure.

The EOQ is calculated using the formula [2,23].:

$$EOQ = \sqrt{\frac{2DS}{H}}$$

Table 1. Review of Symbols Used in the Formula and Software Solution

Symbol	Meaning	Explanation
D	Annual demand	Total yearly demand for a product or material, expressed in units (e.g., pieces).
S	Ordering cost (per order)	Fixed cost incurred each time an order is placed (administration, transport, invoicing, etc.).
H	Annual holding cost per unit	Yearly cost of keeping one unit in inventory (includes storage, insurance, depreciation, obsolescence, and capital).
EOQ	Economic Order Quantity	Optimal order quantity that minimizes the total cost of ordering and holding inventory.

Based on the Economic Order Quantity (EOQ) formula, the following can be concluded:

- If orders are placed too frequently (small order quantities) → ordering costs increase.
- If orders are placed too infrequently (large order quantities) → holding costs increase.
- EOQ represents the equilibrium point between these two cost effects.

Example of EOQ numerical calculation:

Annual demand: $D = 12{,}000$ units,

Ordering cost: $S = €100$,

Holding cost: $H = €2$.

$$\text{EOQ} = \sqrt{\frac{2 \times 12{,}000 \times 100}{2}} = \sqrt{1{,}200{,}000} \approx 1{,}095 \text{ units}$$

Therefore, the optimal order quantity is approximately **1,100 units per order**.

This formula represents the Economic Order Quantity (EOQ), meaning the optimal number of units that should be ordered to minimize total procurement and storage costs.

Alternative EOQ Variant (EKN)

This is a variation of the standard EOQ model, where the variables are expressed using different symbols [20,23]. The calculation formula is:

$$\text{EKN} = \sqrt{\frac{200 \cdot \text{P} \cdot \text{Tn}}{\text{Nc} \cdot \text{Sz}}}$$

or simplified:

$$\text{EKN} = \sqrt{\frac{2 \cdot P \cdot Tn}{Nc \cdot Sz}}$$

Table 2. Symbols Used in the Formula and Software Solution

Symbol	Name	Explanation
P	Consumption	Total annual consumption of the product (in pieces, kg, liters, etc.). Represents how much is consumed per year.
Tn	Ordering cost	Cost incurred each time an order is placed (administrative, transport and related ordering costs).
Nc	Purchase price per unit	Cost of purchasing one unit of product.
Sz (or sz)	Storage cost	Annual holding cost per unit (expressed as a percentage of purchase price or fixed cost per unit).
EKN	Economic order quantity	Optimal quantity to order so that total holding and ordering costs are minimized.

Computation Explanation

- The term **200 · P · Tn** (or **2 · P · Tn** if the values are already annualized) represents **total yearly ordering cost**.
- The term **Nc · Sz** represents **annual holding cost per unit**.
- Taking the square root of the ratio gives the **equilibrium quantity per order**, i.e., the point at which total costs are minimal.

Numerical Example of EKN Calculation

Annual consumption **(P) = 10,000 units**

Ordering cost **(Tn) = 1,000 RSD**

Purchase price **(Nc) = 200 RSD/unit**

Storage cost **(Sz) = 10% = 0.10**

$$\text{EKN} = \sqrt{\frac{200 \times 10{,}000 \times 1{,}000}{200 \times 0.10}} = \sqrt{\frac{2{,}000{,}000{,}000}{20}} =$$

$$= \sqrt{100{,}000{,}000} = 10{,}000$$

In Table 3, the main limitations of the Economic Order Quantity (EOQ) model are presented along with explanations and proposed practical solutions [5,16, 23].

Table 3. EOQ Model Limitations and Possible Solutions

No.	Limitation (Problem)	Practical Consequence	Possible Solution / Adjusted Approach
1	Constant demand (EOQ assumption)	The model does not fit seasonal sales; shortages or excess stock may occur.	Apply dynamic EOQ or demand forecasting for seasonal planning.
2	Fixed purchase price	Ignores promotional discounts, exchange rate fluctuations, and inflation.	Use EOQ with quantity discounts or analyze Total Cost of Ownership.
3	Constant holding cost	In reality, storage costs vary (energy, space, insurance).	Update cost parameters regularly and include variable costs by period.
4	Constant lead time	Delivery delays can cause bottlenecks and stockouts.	Introduce safety stock and a Reorder Point (ROP) system.
5	Unlimited capital and storage space	Optimal quantity may exceed financial or warehouse capacity.	Apply capital and space constraints (Constrained EOQ).
6	Single-item model	Inefficient for large assortments with different characteristics.	Use ABC analysis and apply EOQ only to “A-class” items.
7	No interdependence between items	Does not consider items used together (components).	Introduce Joint EOQ or multi-item inventory models.
8	No shortage cost included	The model ignores losses from unmet demand and dissatisfied customers.	Include shortage cost in the extended EOQ model.
9	Full supplier availability	Assumes supplier always delivers the requested quantity.	Evaluate supplier reliability and ensure a backup source.
10	No market or technology changes	Inventory may become obsolete or lose value.	Include obsolescence risk and apply stock rotation (FIFO, LIFO).

The optimal order quantity is therefore 10,000 units per order to achieve minimum cost.

In Figure 1., the EOQ/EKN curve is illustrated, showing cost behavior for the example provided.

Figure 1. Economic Order Quantity with ordering costs: Orange line – Ordering Cost; Blue line – Holding Cost; Black dashed line – Total Cost; Red dotted line – Optimal point (EOQ ≈ 10,000 units), where total costs are minimized

The EOQ model provides a solid theoretical basis for procurement planning, but real business decision-making requires integration with modern inventory methods such as:

- *Just-in-Time (JIT),*
- *Material Requirements Planning (MRP),*
- *ABC/XYZ analysis,*
- *Forecast-based inventory optimization.*

4.2. ABC/XYZ ANALYSIS

The ABC/XYZ analysis is a method of inventory classification based on item value and consumption dynamics. By combining these two criteria, companies can determine which products require special attention and which are less critical for operations.

ABC analysis is based on the Pareto principle (80/20 rule) and divides inventory into three groups:

- **A items** – small number of items with high value (often 70–80% of total inventory value),
- **B items** – medium value and importance,
- **C items** – large number of low-value, less critical items,
- The primary focus is placed on A items, as they most strongly affect financial and operational stability.

XYZ analysis classifies items according to demand stability and predictability:

- **X items** – stable, highly predictable demand,
- **Y items** – variable, seasonal demand,
- **Z items** – irregular, unpredictable demand.

A combined **ABC/XYZ matrix** makes it possible to define an appropriate control strategy for each category (e.g., AX requires strict monitoring, CZ minimal control).

4.3. JUST-IN-TIME (JIT) SYSTEM

The Just-in-Time system is an inventory management method aimed at eliminating excess stock and producing only what is needed, exactly when it is needed. Core characteristics of JIT include:

- inventories are minimized,
- procurement and production are directly linked to customer orders,
- storage costs and risk of obsolescence are reduced,
- operational efficiency and production flow speed increase.

This system requires a high level of supply chain coordination, reliable suppliers, and precise planning. The most well-known example of successful JIT implementation is **Toyota**, where this model became the foundation of lean manufacturing.

4.4. MRP (MATERIAL REQUIREMENTS PLANNING)

Modern inventory management approaches rely on information systems that integrate purchasing, production, sales, and logistics. MRP is a material planning system based on the production schedule and product structure. Its main functions are:

- determining material requirements,
- scheduling procurement timing,

- reducing surplus inventory and production interruptions.

MRP defines **what** needs to be ordered, **how much**, and **when**.

4.5. ERP (Enterprise Resource Planning)

ERP represents an extended and more advanced version of MRP, as it integrates not only material planning but also [7, 9]:

- procurement,
- production,
- finance,
- sales and CRM,
- warehousing and distribution.

An ERP system provides a unified database and connects all business functions in real time. This significantly improves inventory management, speeds up decision-making, and increases transparency.

Determining inventory requirements involves planning the quantity and timing of procurement. The main objective is to ensure sufficient stock levels in line with the production plan and expected market demand. This process includes analysis of historical data, consumption trends, seasonality, and lead time. In modern systems, **MRP methodology** is used to automatically calculate required material quantities based on planned production.

The **Periodic System (P-System)** implies that inventory levels are checked and replenished at fixed time intervals, regardless of the current stock level. When the review moment arrives, the quantity ordered replenishes inventory up to a predefined maximum level. Its advantage is simplicity of control and suitability for products with stable demand, while the disadvantage is the possibility of stockouts between review intervals, since the system does not respond immediately to demand changes.

The **Continuous System (Q-System)** operates by continuously monitoring inventory levels, issuing a new order as soon as stock reaches the predefined **Reorder Point (ROP)**. The order quantity is usually constant (often equal to the EOQ value). Its main advantage is timely response and reduced stockout risk, while its drawback is more complex monitoring and the need for real-time information.

In practice, companies often combine both systems. The P-system is used when control costs are high and demand is stable (e.g., in grocery retail), while the Q-system is applied to higher-value items where precise tracking is crucial (e.g., automotive and pharmaceutical industries).

Modern information systems enable integration of both models within **ERP and WMS solutions**, enhancing precision and efficiency in inventory management.

5. APPLICATION OF INFORMATION TECHNOLOGY FOR CALCULATING ECONOMIC ORDER QUANTITY (EOQ)

Python program solution with algorithm development steps [1, 23]:

EOQ is calculated using the formula:

$$EOQ = \sqrt{\frac{200 \cdot P \cdot T_n}{N_c \cdot S_z}}$$

Where:

P – annual consumption (units/year)

Tn – cost per order

Nc – purchase price per unit

Sz – annual holding cost per unit

Algorithm:

1. Input values: *P, Tn, Nc, Sz*
2. Compute the numerator: numerator = 200 * P * Tn
3. Compute the denominator: denominator = Nc * Sz
4. Compute the ratio: ratio = numerator / denominator
5. Calculate the square root: EOQ = sqrt(ratio)
6. Display the result to the user

Optionally, additional cost values may also be calculated (not mandatory but useful):

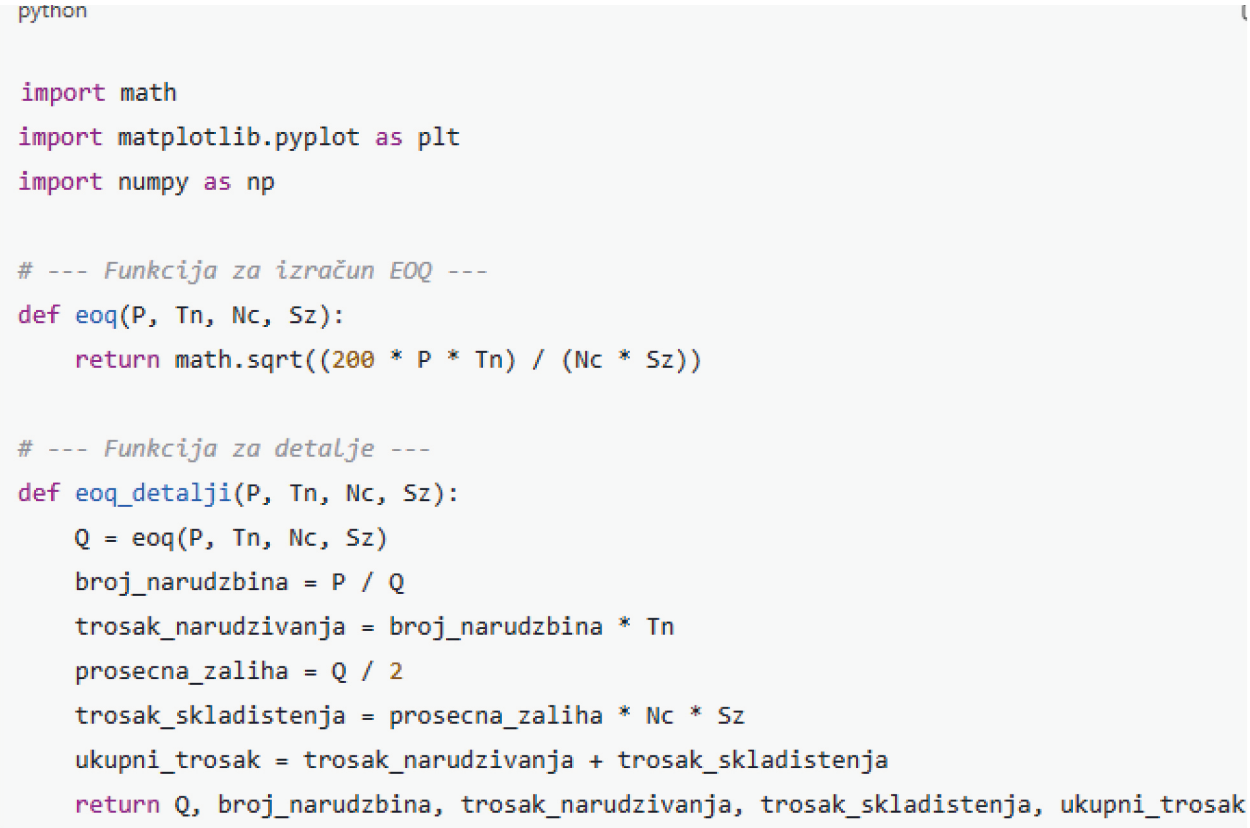
- Number of orders per year: N = P / EOQ
- Annual ordering cost: $C_n = N \cdot T_n$
- Average inventory level: Z = EOQ / 2
- Annual holding cost: $C_s = Z \cdot N_c \cdot S_z$
- Total annual cost: $C_{total} = C_n + C_s$

Python program solution

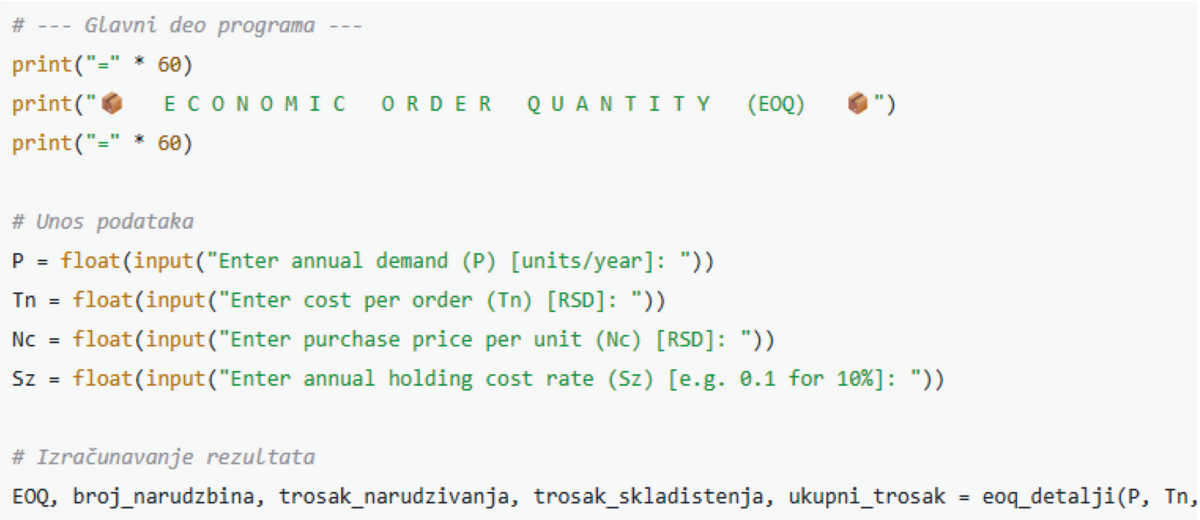
Below is a Python program version that generates a cost graph based on the entered data 1,23].

The program can be run as follows:

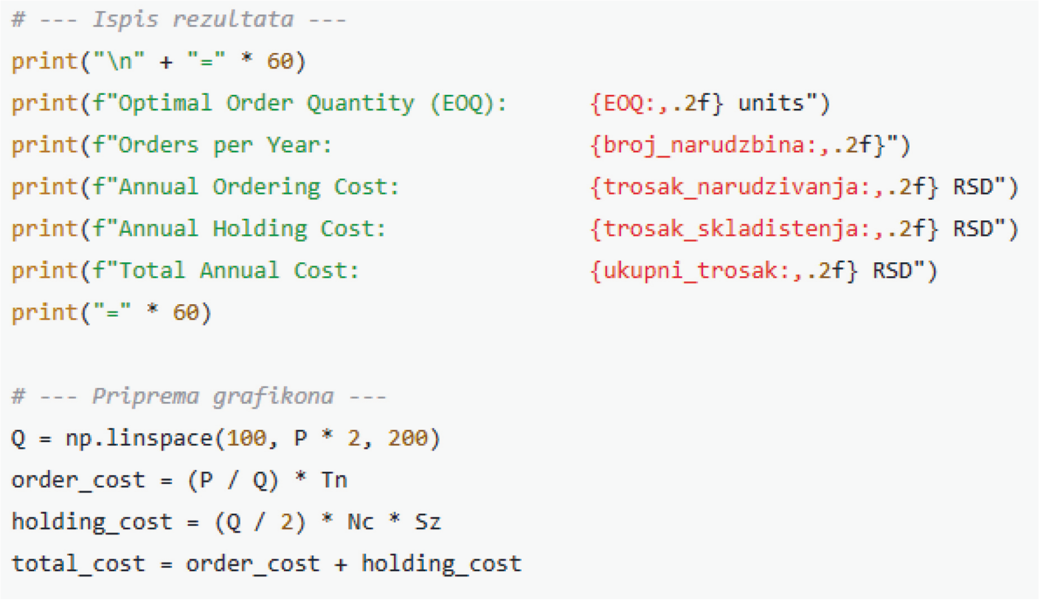
1. When the program starts, enter the following four inputs:
   - annual consumption (P)
   - ordering cost (Tn)
   - unit purchase price (Nc)
   - annual holding cost per unit (Sz)
2. The program calculates the EOQ and all related costs.
3. It prints the results in bold format.



```python
import math
import matplotlib.pyplot as plt
import numpy as np

# --- Funkcija za izračun EOQ ---
def eoq(P, Tn, Nc, Sz):
    return math.sqrt((200 * P * Tn) / (Nc * Sz))

# --- Funkcija za detalje ---
def eoq_detalji(P, Tn, Nc, Sz):
    Q = eoq(P, Tn, Nc, Sz)
    broj_narudzbina = P / Q
    trosak_narudzivanja = broj_narudzbina * Tn
    prosecna_zaliha = Q / 2
    trosak_skladistenja = prosecna_zaliha * Nc * Sz
    ukupni_trosak = trosak_narudzivanja + trosak_skladistenja
    return Q, broj_narudzbina, trosak_narudzivanja, trosak_skladistenja, ukupni_trosak
```



```python
# --- Glavni deo programa ---
print("=" * 60)
print("📦   E C O N O M I C   O R D E R   Q U A N T I T Y   (EOQ)   📦")
print("=" * 60)

# Unos podataka
P = float(input("Enter annual demand (P) [units/year]: "))
Tn = float(input("Enter cost per order (Tn) [RSD]: "))
Nc = float(input("Enter purchase price per unit (Nc) [RSD]: "))
Sz = float(input("Enter annual holding cost rate (Sz) [e.g. 0.1 for 10%]: "))

# Izračunavanje rezultata
EOQ, broj_narudzbina, trosak_narudzivanja, trosak_skladistenja, ukupni_trosak = eoq_detalji(P, Tn,
```



```
# --- Ispis rezultata ---
print("\n" + "=" * 60)
print(f"Optimal Order Quantity (EOQ):      {EOQ:,.2f} units")
print(f"Orders per Year:                   {broj_narudzbina:,.2f}")
print(f"Annual Ordering Cost:              {trosak_narudzivanja:,.2f} RSD")
print(f"Annual Holding Cost:               {trosak_skladistenja:,.2f} RSD")
print(f"Total Annual Cost:                 {ukupni_trosak:,.2f} RSD")
print("=" * 60)

# --- Priprema grafikona ---
Q = np.linspace(100, P * 2, 200)
order_cost = (P / Q) * Tn
holding_cost = (Q / 2) * Nc * Sz
total_cost = order_cost + holding_cost
```

```
# --- Crtanje grafikona ---
plt.figure(figsize=(9,6))
plt.plot(Q, order_cost, label='Ordering Cost', color='orange', linewidth=3)
plt.plot(Q, holding_cost, label='Holding Cost', color='deepskyblue', linewidth=3)
plt.plot(Q, total_cost, label='Total Cost', color='black', linestyle='--', linewidth=3.5)
plt.axvline(EOQ, color='red', linestyle=':', linewidth=4, label=f'EOQ ≈ {EOQ:.0f} units')

plt.title('Economic Order Quantity (EOQ)', fontsize=18, fontweight='bold')
plt.xlabel('Order Quantity (Q)', fontsize=15, fontweight='bold')
plt.ylabel('Cost (RSD)', fontsize=15, fontweight='bold')
plt.legend(fontsize=13, loc='upper left', frameon=True)
plt.grid(True, linewidth=0.8)
plt.tight_layout()
plt.show()
```

4. It generates a graph with bold lines and a clearly marked optimal EOQ point.

Algorithm and Python program for calculating Maximum Purchase Need (MPN) when demand is uncertain [1,23].

1. Algorithm (steps)

We use the formula:

$$MPN = P \cdot T + F_{Zn} \cdot \sqrt{P \cdot q \cdot T}$$

Inputs:

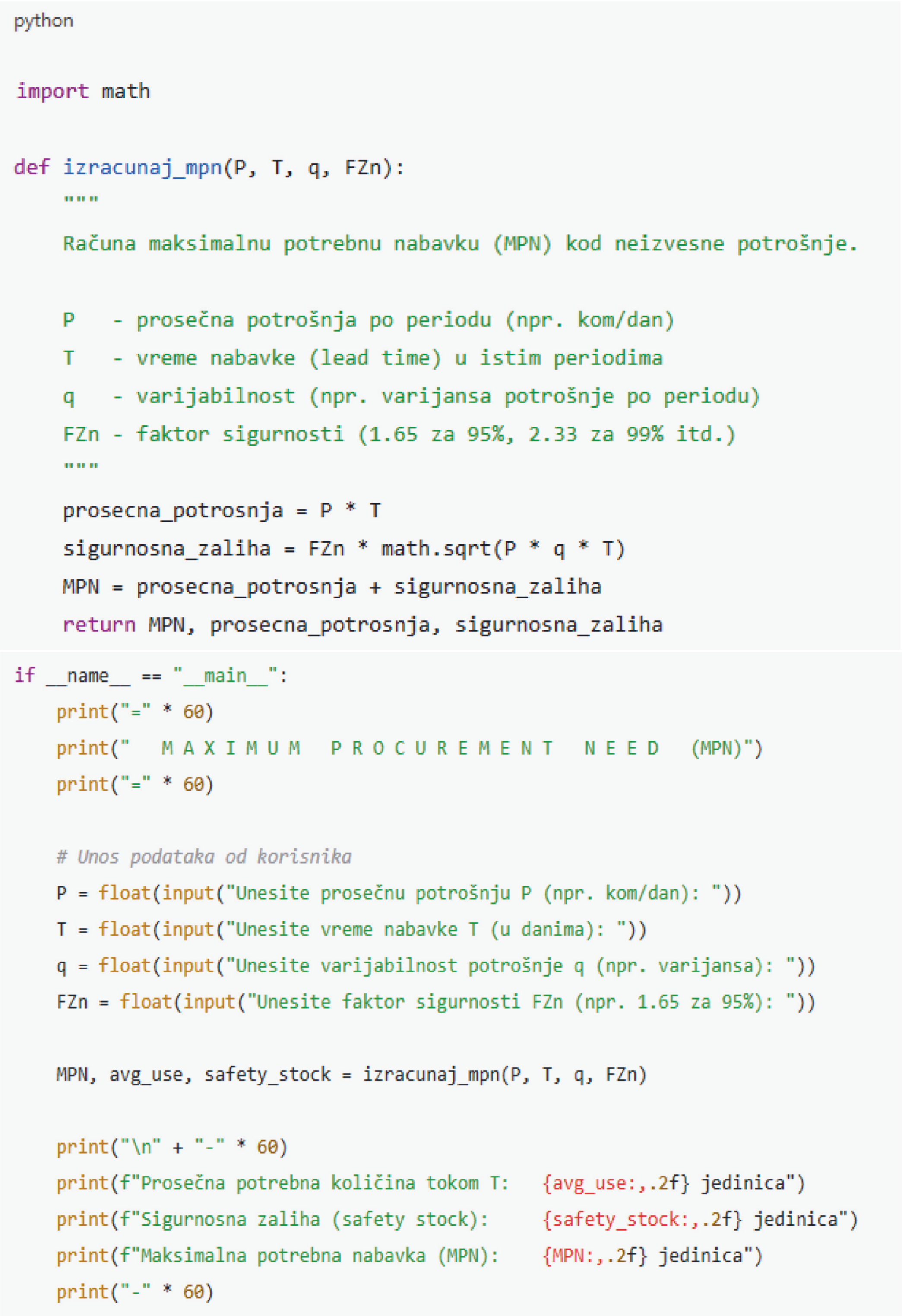
- P – average demand per period (e.g., units/day)
- T – lead time in the same period units (e.g., days)
- q – demand variability (variance or another variability indicator)
- FZn – safety factor (e.g., 1.65 for 95% service level)

Outputs:

- MPN – maximum required purchase quantity
- average consumption during T
- safety stock

Steps:

1. Load/enter values for *P, T, q, FZn*.
2. Compute: average_consumption = P * T
3. Compute safety stock:
$$safety\_stock = F_{Zn} \cdot \sqrt{P \cdot q \cdot T}$$
4. Compute maximum purchase need:
$$MPN = average\_consumption + safety\_stock$$
5. Print **MPN**, **average_consumption**, and **safety_stock**.



```python
python

import math

def izracunaj_mpn(P, T, q, FZn):
    """
    Računa maksimalnu potrebnu nabavku (MPN) kod neizvesne potrošnje.

    P   - prosečna potrošnja po periodu (npr. kom/dan)
    T   - vreme nabavke (lead time) u istim periodima
    q   - varijabilnost (npr. varijansa potrošnje po periodu)
    FZn - faktor sigurnosti (1.65 za 95%, 2.33 za 99% itd.)
    """
    prosecna_potrosnja = P * T
    sigurnosna_zaliha = FZn * math.sqrt(P * q * T)
    MPN = prosecna_potrosnja + sigurnosna_zaliha
    return MPN, prosecna_potrosnja, sigurnosna_zaliha
if __name__ == "__main__":
    print("=" * 60)
    print("   M A X I M U M   P R O C U R E M E N T   N E E D   (MPN)")
    print("=" * 60)

    # Unos podataka od korisnika
    P = float(input("Unesite prosečnu potrošnju P (npr. kom/dan): "))
    T = float(input("Unesite vreme nabavke T (u danima): "))
    q = float(input("Unesite varijabilnost potrošnje q (npr. varijansa): "))
    FZn = float(input("Unesite faktor sigurnosti FZn (npr. 1.65 za 95%): "))

    MPN, avg_use, safety_stock = izracunaj_mpn(P, T, q, FZn)

    print("\n" + "-" * 60)
    print(f"Prosečna potrebna količina tokom T:   {avg_use:,.2f} jedinica")
    print(f"Sigurnosna zaliha (safety stock):     {safety_stock:,.2f} jedinica")
    print(f"Maksimalna potrebna nabavka (MPN):    {MPN:,.2f} jedinica")
    print("-" * 60)
```

The file can be executed using: python mpn_calc.py

The formula for Optimal Storage Time (OST) represents the period during which goods should remain in storage so that ordering and holding costs are balanced and minimized.

Optimal Storage Time is calculated as [18,23].:

$$OST = \sqrt{\frac{2 \cdot T_n}{N_c \cdot q \cdot P \cdot q}}$$

In practice, the commonly used simplified form is:

$$OST = \sqrt{\frac{2 \cdot T_n}{N_c \cdot q \cdot P}}$$

Table 4. presents the explanation of symbols used for calculating Optimal Storage Time (OST).

Table 4. Meaning of Symbols for OST Calculation

Symbol	Meaning	Explanation
OST	Optimal Storage Time	Indicates how many days (weeks/months) goods should remain in stock on average before reordering.
Tn	Ordering cost per order	Includes administrative, transport, and other purchasing expenses.
Nc	Unit purchase price	Price of one item, used to calculate storage cost.
q	Holding cost rate per unit	Usually expressed as an annual percentage (e.g., 0.1 = 10%).
P	Annual demand	Quantity of product consumed per year.

This formula represents the **time equivalent of EOQ**. While EOQ shows **how much to order**, OST shows **when to order**, i.e., the optimal time interval between orders.

In other words, OST indicates the length of one replenishment cycle — the time required to deplete the stock from one optimal purchase.

In the following Table 1.4, parameter values for OST calculation are provided:

Table 5. Parameters for the Calculation

Parameter	Symbol	Value
Ordering cost	T_n	1,000 RSD
Purchase price	N_n	200 RSD
Holding cost rate	q	0.1 (10%)
Annual demand	P	12,000 units

$$OST = \sqrt{\frac{2 \cdot 1{,}000}{200 \cdot 0.1 \cdot 12{,}000}}$$

$$OST = \sqrt{\frac{2{,}000}{240{,}000}} = \sqrt{0.00833} = 0.0913 \text{ years} \approx 33 \text{ days}$$

The optimal storage time is approximately **33 days**, meaning that the most economical ordering frequency is **about once per month**, where holding and ordering costs are in balance.

5.1. Critical Analysis of the Applied Models

Classical inventory models (EOQ, ABC/XYZ, JIT, MRP/ERP) have undeniably contributed to the development of modern logistics systems; however, each carries specific limitations:

Table 5. Advantages and Limitations of Classical Models (EOQ, ABC/XYZ, JIT, MRP/ERP)

Model	Advantages	Limitations
EOQ	Simple, fast calculation, reduces ordering costs	Ignores seasonality, demand fluctuations, and lead-time variability
ABC/XYZ Analysis	Clear item segmentation, focus on critical stock	No automated decision-making, highly dependent on data quality
JIT	Minimal inventory, lean production, lower storage costs	Highly sensitive to supply chain disruptions
MRP/ERP	Integrated system, full material flow control	High implementation cost and requirement for skilled personnel

On the other hand, artificial intelligence offers the potential to overcome many of these limitations; however, AI is not a universal solution. The main challenges include the need for large volumes of high-quality data, the financial cost of implementation, and organizational change required for digital transformation.

The conclusion of this critical analysis is that no single model is sufficient on its own — a combination of classical methods and AI provides the most effective approach to modern inventory management.

6. ARTIFICIAL INTELLIGENCE IN INVENTORY MANAGEMENT

In recent years, inventory management has undergone significant transformation due to the implementation of Artificial Intelligence (AI). Traditional inventory planning and optimization models relied on historical data and static algorithms, whereas modern AI technologies enable automated analysis of large data sets, real-time demand forecasting, and decision-making that reduces costs and increases operational efficiency. As a result, AI has become a key component of contemporary supply chain management, especially in industries with high demand variability and frequent fluctuations [6, 15, 19, 24].

6.1. THE ROLE OF AI IN INVENTORY OPTIMIZATION

Artificial intelligence improves inventory management through automated analytics, forecasting, and decision-making. Instead of manual planning and fixed ordering models, AI-based systems autonomously propose optimal order quantities, identify potential stockout risks, and reduce total costs.

Predictive analytics uses historical sales data, seasonality patterns, and market trends to estimate future stock requirements. AI models detect hidden patterns that traditional methods often miss, enabling more accurate ordering and reducing excess inventory — particularly valuable in retail and manufacturing sectors where demand fluctuates daily.

Demand forecasting:

AI systems provide advanced forecasting capabilities using hundreds of input variables, including price changes, marketing campaigns, global events, seasonality, and customer behaviour. Improved forecasting accuracy leads to better procurement planning, fewer delivery delays, and lower inventory holding costs.

Behavioural pattern recognition:

Machine learning algorithms analyse customer habits and detect purchase trends, frequency of orders, and product popularity. The system automatically identifies items with increasing demand and recommends timely replenishment, improving product availability and preventing profit loss caused by stockouts.

6.2. KEY AI TECHNOLOGIES

The application of artificial intelligence in logistics and inventory management relies on several technological principles. The most commonly used technologies include:

- **Machine Learning (ML)**

ML algorithms learn from data and improve their predictions over time. In inventory management, ML is used for:

– demand forecasting,
– procurement optimization,
– automated reordering,
– anomaly detection in consumption and stock levels.

ML models become increasingly accurate as more data is generated, leading to long-term cost reduction and improved strategic decision-making.

Deep Learning

Deep Learning applies multi-layer neural networks that simulate the way the human brain processes information. These systems are highly effective in complex environments with numerous variables — e.g., seasonality, geographical demand variations, and time-dependent trends. Deep Learning can predict demand trends even when patterns shift unexpectedly.

Large Language Models (LLMs), such as ChatGPT

LLMs enable automation of communication and decision-making based on textual data. In inventory management, they can:

– analyse orders and generate procurement recommendations,
– produce reports and forecasts,
– communicate with suppliers and customers,
– serve as AI assistants within logistics departments.

Integration of LLMs reduces administrative workload and accelerates information processing.

AI-integrated ERP systems

Modern ERP solutions (SAP, Oracle, Microsoft Dynamics) increasingly include AI modules that automatically optimize inventory and orders. The system can:

- track inventory levels in real time,
- forecast stock-out periods,
- generate purchase orders,
- balance inventory turnover and cost.

AI within ERP environments enables centralized inventory control while reducing the risk of human error.

6.3. BENEFITS AND CHALLENGES OF AI IN INVENTORY MANAGEMENT

AI brings significant operational advantages but also challenges that organizations must consider.

Benefits:

- substantially increased accuracy of demand forecasts,
- faster decision-making and process automation,
- lower storage and holding costs,
- reduced risks of shortages and overstock,
- improved customer satisfaction and product availability,
- real-time analytics and greater supply chain flexibility.

Challenges:

- requirement for large volumes of high-quality data,
- high initial implementation cost,
- need for skilled personnel to operate AI systems,
- risk of technological dependency and cybersecurity exposure.

Although AI requires strong digital infrastructure and financial investment, the efficiency gains, cost savings, and better inventory availability make it one of the most promising tools for modern supply chain management.

6.4. CASE STUDIES

The impact of artificial intelligence in inventory management is most evident in real-world examples of leading global companies. The following case studies illustrate how AI enhances storage operations, forecasts demand, reduces costs, and increases market availability. Each example includes the initial challenge, the applied AI solution, and measurable results.

6.4.1. ADIDAS — AI-DRIVEN DEMAND FORECASTING

Adidas, one of the world's largest sports brands, operates with a wide product portfolio and highly seasonal demand patterns. Efficient global stock management required accurate sales forecasting to prevent overstocking and delays.

Challenges before AI:

- inaccurate demand forecasts for specific models and sizes,
- surplus stock in some regions and shortages in others,
- longer delivery times and slower inventory turnover.

AI-based solution:

- application of machine learning models for forecasting,
- analysis of historical sales data and seasonal fluctuations,
- automated stock allocation across markets based on predictions.

Results:

- up to 30% more accurate demand forecasting,
- faster inventory turnover and reduced warehousing costs,
- improved product distribution across sales channels,
- reduced losses from unsold seasonal products.

6.4.2. AMAZON — ROBOTIC WAREHOUSING & AUTOMATIC REPLENISHMENT

Amazon operates one of the largest logistics networks globally, where delivery speed and product availability are critical success factors. AI is integrated into nearly every layer of the supply chain.

Challenges before AI:

- manual inventory handling was slow, costly, and error-prone,
- large workforce needed for physical item movement,
- continuous growth in order volume required higher efficiency.

AI-based solution:

- implementation of robotic warehouses (Amazon Robotics),
- autonomous robots transporting shelves and tracking item location,
- AI algorithms for automated replenishment and routing.

Results:

- up to 50% faster order processing,
- reduced warehouse operating costs,
- more accurate item handling with fewer delivery errors,
- ability to achieve 24-hour delivery in most regions.

6.4.3. WALMART – BIG DATA + FORECASTING + SUPPLY CHAIN AI

Walmart operates more than 10,000 retail locations worldwide and manages millions of SKUs (items). The complexity of such a logistics network required advanced forecasting and inventory management methods.

Challenges before AI:

- variable demand and frequent stockouts,
- large differences in consumer behaviour across regions,
- manual procurement planning was slow and inaccurate.

AI solution:

- implementation of big data forecasting algorithms,
- real-time customer behaviour analytics,
- integration of AI into ERP and supply chain procurement systems.

Results:

- over 20% reduction in out-of-stock occurrences,
- faster procurement decisions and more stable inventory levels,
- higher product availability and increased customer satisfaction,
- improved logistics cost optimization in transportation and warehousing.

6.4.4. TOYOTA – JUST-IN-TIME + AI OPTIMIZATION

Toyota is the pioneer of Lean manufacturing and the Just-in-Time philosophy. Under JIT, inventory levels are minimized and production flows in real time according to demand. With the integration of AI technology, the model was further strengthened.

Challenges before AI:

- sensitivity of JIT to supplier delays,
- lack of flexibility during sudden demand surges,
- risk of production interruptions due to low inventory buffers.

AI solution:

- integration of AI into procurement and warehouse planning,
- predictive analytics for supplier risks and potential delays,
- digital factory control systems with real-time operational data.

Results:

- up to 35% fewer production stoppages,
- more secure JIT distribution and a more resilient supply chain,
- reduced safety stock without loss of efficiency,
- faster response to market fluctuations and demand shifts.

6.5. DISCUSSION AND RECOMMENDATIONS FOR FUTURE RESEARCH - OPEN QUESTIONS

The research indicates that technological development has fundamentally reshaped inventory management. However, several future research directions could further improve theoretical understanding and practical application:

Recommendations for future research

1. Deep analysis of AI-based demand forecasting algorithms: Emphasis should be placed on comparing different machine-learning models under real market conditions.
2. Examination of AI impact on decision-making and organizational culture: Human roles, decision-making processes, and technology adoption require a socio-technical perspective.
3. Research on IoT integration in warehouse systems: Internet of Things (IoT) technology enables real-time inventory tracking and higher automation potential.
4. Study of ethical and cybersecurity implications in digital supply chains: Data privacy, cybersecurity protection and AI-bias issues are becoming increasingly important.

7. CONCLUSION

Inventory represents an essential component of every supply chain and plays a crucial role in maintaining business continuity. Inventory management is one of the key elements of efficient operation, particularly in the modern global environment characterized by unpredictable demand and rapid market fluctuations. The analyzed models — ranging from classical frameworks such as EOQ, ABC/XYZ classification, JIT, and MRP/ERP systems, to modern solutions based on artificial intelligence — demonstrate that inventory management is not a static, but rather a dynamic system that continuously adapts to changing conditions. Proper inventory planning and control enhance efficiency, reduce total costs, and strengthen customer relationships.

Contemporary trends emphasize inventory optimization through integrated information systems, warehouse automation, and the development of concepts such as Just-in-Time (JIT), Lean, and Vendor Managed Inventory (VMI). The goal is not to eliminate inventory, but to manage it intelligently — in a way that supports the company's strategy and the entire supply chain. Traditional methods provide a stable basis for planning and cost control, while AI-driven approaches enable smarter, faster, and more flexible resource management. The combination of both strategies ensures optimal utilization, reduces shortages and overstock situations, improves inventory turnover, and increases profitability. Case studies of global companies (Adidas, Amazon, Walmart, Toyota) confirm that the application of artificial intelligence is not merely a theoretical concept, but a measurable and practically proven tool with real results.

In general, the future of inventory management is moving toward digitalization, automation, and predictive modelling. Organizations that integrate artificial intelligence into their supply chain processes will be better positioned to maintain competitiveness, reduce costs, and respond to market shifts in real time.

The research confirms that modern information technologies significantly improve inventory efficiency and overall supply chain performance. The use of integrated IT systems (ERP, MRP, WMS) reduces total holding and ordering costs. Digital transformation increases data accuracy and real-time visibility. Automated procurement and planning processes enhance decision-making speed, reliability, and responsiveness.

The analysis also highlights one of the major challenges — the lack of IT infrastructure and skilled personnel remains a key barrier to the effective implementation of digital inventory management systems.

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САВРЕМЕНЕ ИНФОРМАЦИОНЕ ТЕХНОЛОГИЈЕ И ЊИХОВА ПРИМЕНА У УПРАВЉАЊУ ЗАЛИХАМА

Резиме: *Залихе имају централну улогу у ланцу снабдевања и повезују сваку фазу – од набавке до продаје. Ефикасно управљање залихама доприноси смањењу трошкова, повећању профитабилности и јачању конкурентске предности. Савремена предузећа суочавају се са изазовима попут глобализације, променљиве потражње и потребе за брзом реакцијом на тржишне промене. Из тог разлога, дигитализација процеса управљања залихама постала је кључни предуслов за конкурентност и одрживо пословање.*

Управљање залихама представља један од најважнијих елемената ефикасног пословања. Ефективна контрола залиха омогућава организацијама да смање трошкове, повећају ликвидност и унапреде задовољство купаца. Циљ овог рада је да прикаже традиционалне и модерне моделе управљања залихама, са посебним нагласком на примену информационих технологија и вештачке интелигенције. Општи циљ је да се истражи и покаже улога информационих технологија у унапређењу процеса управљања залихама и њихов утицај на пословну ефикасност – смањење укупних трошкова набавке и складиштења, повећање брзине и поузданости одлучивања, обезбеђивање веће тачности података и боље контроле над кретањем залиха.

Предмет овог истраживања је анализа значаја и утицаја информационих технологија на планирање, контролу и оптимизацију залиха у предузећима из различитих индустрија. У савременом пословном окружењу, информациона технологија (ИТ) има кључну улогу у унапређењу управљања залихама и повећању ефикасности ланца снабдевања. У раду је такође приказано софтверско решење засновано на програмском језику Путхон за израчунавање економске количине наручивања (EOQ).

У истраживању ће бити примењена комбинација квалитативних и квантитативних метода. За обраду и анализу података користиће се статистичке методе (дескриптивна статистика, корелациона анализа, регресиони модели), уз примену софтверских алата попут Ехцела или СПСС-а.

Разумевање сврхе, категорија и система управљања залихама омогућава предузећима да постигну оптималну равнотежу између доступности производа и трошкова држања залиха. Савремена пракса све више се ослања на дигитализацију и моделе предвиђања који унапређују доношење одлука и чине ланац снабдевања отпорнијим и ефикаснијим.

Кључне речи: *информационе технологије, вештачка интелигенција, дигитализација, ланац снабдевања, залихе, економска количина наручивања*