A Comparative Review of Inventory Models: Strengths, Weaknesses, and Applicability

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Abstract

Inventory management is significant in operations of supply chain including different types of models to improve service quality, cost minimization and optimization of stock levels. The comparative review explores about the strengths, weaknesses, and applicability of major inventory models like vendor-managed inventory and Economic order quantity. The model can be evaluated for different types of parameters that include suitability, demand variability adaptability, implementation ease and cost efficiency for various industries. The review includes the contextual factors to enhance the performance of model like organizational structure, type of product and market dynamics. The model analyses provide insights with inventory strategy to enhance the competitiveness and operational efficiency. The findings of the study provide the real-world applications of the inventory models.

Keywords: *Inventory models, deterministic, stochastic, applicability, strength, weakness*

1. Introduction

Inventory modelling is crucial in modern supply chain management, as it requires a deep understanding of how inventory dynamics interact with market uncertainties. This research thoroughly examines both deterministic and stochastic approaches to inventory modeling, offering valuable insights for businesses facing the challenges of unpredictable market conditions. In today's global economy, companies are constantly dealing with volatility and uncertainty. Traditional deterministic inventory models, which depend on fixed parameters and assume steady demand, struggle to capture the complexity of real-world markets. Unexpected changes in market trends or events like pandemics can disrupt these models, leading to inventory levels that don't match actual demand. This misalignment can result in lost revenue due to stockouts or high holding costs, highlighting the need for a more flexible and resilient approach. Conversely, the stochastic approach recognizes the natural variability in market dynamics, making it essential for businesses to consider the impact of uncertainty on inventory management in an environment where demand fluctuations are the norm.

Inventory modeling facilitates an understanding of production systems by constructing, solving, and analysing a representation of real-world operations. This process enables effective management of operations across various types of companies or supply chain networks. The aim of this research is to conduct a comprehensive review of deterministic and stochastic inventory models within production systems. The proposed methodology consists

of three stages including search design that involves search strategies, information sources and guiding questions, selection process that involves criteria and chosen studies and synthesis of results. The findings reveals the significance of various inventory models, both independently and in combination, particularly Simulation and optimization modes in stochastic system and Optimization linear programming, Queue models and Economic production quantity in deterministic system in management of supply chain (Vidal., 2023).

1.1 Review objectives

The objectives are discussed below;

- To compare the strengths and weaknesses in different types of inventory models
- To analyse deterministic and stochastic model
- To examine the real-world applications of inventory models

2. Review on Deterministic Inventory Models

The concept of the model is based on the specific practical constraints and assumptions in the supply chain. Following this discrete mathematical inventory model is developed to capture the system's elements and their interactions. This model includes deterministic and stochastic demand, variable lead times, multiple pharmaceutical products and various ordering policies, such as Fixed order quantity and Lot for Lot. Deterministic demand is represented by forecasting o0f monthly sales for every product, whereas stochastic demand is modelled for forecasting the sales within a ±20% range as random variation. Two objective functions are established like one aims to maximize the difference among the realized average of inventory level and planned average of inventory level, while the other seeks to minimize stock-out occurrences (Antic et al., 2022).

Table 1. Review on Deterministic Inventory Models

References	Methods	Findings
2019		
Stopkova et al., (2019)	Effective inventory management by deterministic multi-objective model	Suppliers' reliability, means of transport capacity, inventories shares and inventory consumption parameters are modified for increased effectiveness
2020		
Ozturk., (2020)	Deterministic model for backorder shortages, rework process and defective items	The model identifies the imperfect production that consists of reworkable items, poor quality and scraps.
2021		
Wei et al., (2021)	Service level constraint with	To control service quality and

	deterministic approximation	management of stockout with positive lead times and independent demands
2022		
Benkherouf & Gliding., (2020)	Optimal policies for deterministic model	To determine replenishment schedule for minimising the total cost of holding and stocking inventory
2023		
Aladwani et al., (2023)	Optimal inventory policies	Permissible payment delay, deteriorating items and time varying demand are analysed.
2024		
Adebayo et al., (2024)	Inventory control framework for finished goods	Sales projection was addressed for an item. Stock-out circumstance minimization, acknowledged stock and mean stock level with pragmatic presumptions

3. Review on Stochastic Inventory Models

Inventory system effectively manage materials but sometimes it has negative impact the relationship between the customers and facility in material management. Sufficient on-hand inventory met immediate demands in conventional inventory models. The researcher introduced stochastic inventory mathematical model that incorporates impatient, considering uniform and deterministic order sizes. The inventory model analyses the measures of performance in the stochastic environment by evaluating the inventory model properties with probabilistic and stochastic parameters and by validating the accuracy of the model. The system can be examined by balance equations that derives from mathematical characterization using Markov chain based on underlying queuing model. Precise performance was assessed by analysing service process with graphical representation in a steady state, considering both coefficient of customer patience and arrival distribution. However, deriving an optimal curve fit in a three-dimensional space with one input and two input variables proved challenging (Alnowibet et al., 2022).

Table 2. Review on Stochastic Inventory Models

References	Methods	Findings
2019		
Canyakmaz et al., (2019)	Stochastic price process inventory model	Lost-sale and backorder cases are analysed. It extends as a price-modulated compound with

		various parameters.
2020		
Waliv et al., (2020)	Non-linear approach using uncertain information	The parameters used in the inventory model are shortage costs, purchasing cost and capital investment
2021		
Tai et al., (2021)	Inventory model for lead time and discrete demand	The model estimates the performance accurately for over-storage amount and expected inventory
2022		
Jauhari & Wangsa., (2022)	Retailer-Manufacturer inventory model	Minimizing of joint total cost subjected to supply chain management to find the collection rate, shipment quantity, investment amount and number of shipments
2023		
Khedlekar et al., (2023)	Stochastic inventory model with promotional efforts restricted shortage and price-sensitive demand	To boost up the market demand, preserve the rate of rate of deterioration, proportionate partial backlogging and shortage time with optimal technology
Nozari et al., (2023)	Stochastic inventory models for transport companies	It determines the amount of trucks, transport containers and cargo stored in appropriate locations with new fuzzy-probabilistic method to control the parameters
2024		
Gupta & Mishra., (2024)	Multi-item inventory model with power stochastic demand pattern	To reduce the total cost per unit by obtaining the optimal stock amount to protect overstocking and excessive lost sales

4. Comparative Analysis of inventory models

This research study offers an in-depth comparison between two essential approaches to inventory modelling: deterministic and stochastic. The deterministic model utilizes traditional optimization techniques to manage complex systems, while the stochastic model applies Particle Swarm Optimization (PSO) simulations to address the challenges of uncertain dynamics. This allows for the development of effective strategies for optimizing complex systems. Sensitivity analyses revealed that the deterministic model tends to oversimplify demand dynamics, whereas the stochastic model more accurately reflects market uncertainties. Consequently, the study recommends that businesses adopt stochastic methods for inventory management to enhance adaptive decision-making, contingency planning, optimal resource allocation, risk mitigation, and realistic performance metrics. The findings provide valuable guidance for businesses aiming to navigate the intricacies of modern supply chain (Kumar et al., 2024).

Table 3. Comparative Analysis of inventory models

References	Methods	Findings
2020		
Biuki et al., (2020)	Integrated routing-location inventory model	Optimal solution is found using particle swarm optimization and genetic algorithm for integrated decision making on inventory control, routing and location and to solve sustainability issue
2021		
Ahmadini et al., (2021)	Multi-objective optimization model for green supply chain	To maximize profit ratio, cost minimization, minimization of waste and total penalty cost. To provide suggestion to the decision makers
Shokouhifar et al., (2021)	Fuzzy demand and supply chain with inventory model	Whale optimization algorithm is used for lateral transshipment, wastage, shortage and inventory holding.
2022		
Alkahtani., (2022)	Mathematical inventory modelling	To solve outsourcing problem by considering imperfect production in supply chain management.

2023		
Maheswari et al., (2023)	Sustainable inventory model	Remanufacturing model and resource-efficient network is developed to save natural resources by maintaining the item flow and pressure reduction in the environment.
Modares et al., (2023)	Vendor-managed model for reliability and selection of optimal retailers	To establish relationship between retailer and vendor with optimal selection. Redundancy allocation problem is used effectively.
2024		
Vaka., (2024)	Integration of distribution and inventory management	To attain enhanced service quality and reduced costs that involves competitiveness among companies, inventory expenses, facility and transportation.

According to the existing studies related to inventory models, the strengths and weaknesses of the models are considered to be more important to analyse the impact on various improvement of businesses.

Strengths of inventory models

- Resource Optimization can be performed using inventory models to determine the efficient use of resources, cost reduction and optimal inventory levels.
- Most of the models incorporate demand forecasting that enables the organization to change the inventory levels and future needs by reducing excess inventory and stockout risks.
- Most of the models offers decision making with structured approach that helps the managers to choose the best strategies for distribution stocking and ordering of goods.
- Through optimization of inventory models cost reduction can be achieved through altering of order quantities by reducing the cost in emergency orders, stockouts and overstocking.
- Customer satisfaction can be improved by meeting the customer demand with optimal inventory levels.
- Stochastic models can adopt to the upgrading market conditions when compared with deterministic models. It helps the businesses to be more flexible according to the fluctuations in demand.

Weakness of inventory models

- The effectiveness and accuracy of the inventory models depends on the quality and availability of data. Inaccurate and incomplete data may lead to wrong decision making.
- Advanced inventory models include AI driven algorithms and stochastic processes that are more complex and requires special skill for implementation.
- Implementation of few models requires system integration or new software that are time consuming and expensive.
- Conventional models assume lead times and constant demand that are not reflected in real world which may lead to poor performance.
- Some inventory models have limited scope and some deterministic models cannot accommodate the sudden change in supply chain and demand chain.

5. Real-world applications of Inventory modelling

Maintaining optimal inventory levels within supply chains is a delicate balancing act. Too little inventory can result in stockouts, lost sales, and unhappy customers, while too much inventory leads to high storage and carrying costs, along with the risk of product obsolescence. AI-driven inventory optimization techniques use various algorithms and machine learning models by which the challenges are addressed. Dynamic programming algorithms can be identifies with optimal; inventory levels by considering the capabilities of suppliers, lead times and demand forecasting. Reinforcement learning algorithms can be employed in simulated environments to develop inventory policies that adapt to fluctuating market conditions. By leveraging AI-powered optimization, businesses can minimize carrying costs, shorten lead times, and ensure consistent product availability across the supply chain (Gayam et al., 2021).

The stochastic counterpart problems are addressed using two mixed integer programming models. The first model incorporates factors such as expiration dates, required emergency purchases, age-based inventory levels, perishability and require service levels. It supports decision-making related to inventory management, supplier selection and replenishment of medicines. The effectiveness of the model has been assessed using both simulated scenarios and real data. The findings indicate that the optimal policy can reduce current hospital management and supply costs for medicine planning by 16%, covering 22 different medicines. The second model is a bi-objective optimization model, solved using the epsilon-constraint method. It focuses on determining the maximum acceptable expiration date, with the goal to minimize the amount on expired medicines (Franco & Alfonso-Lizarazo., 2020).

Inventory control and management are essential for business owners and entrepreneurs to develop effective strategies that enhance profitability. This becomes especially critical in industries such as manufacturing, food production, and pharmaceuticals, where inventory issues are prevalent. An optimization model for inventory control in distribution enterprises was established for minimizing the average total cost within the inventory system per unit

time. While many researchers have attempted to improve inventory control and policies over the past decade, the dynamic nature of human behavior makes it challenging to create a perfect, one-size-fits-all inventory solution for all business sectors. In this study, data collected from various research works, questionnaires, and interviews will be used to apply an artificial neural network (ANN) approach to provide an optimized solution. The model we developed yields accurate, cost-effective results, which can be valuable for inventory researchers seeking suitable techniques for determining economic order quantity systems or formulating new inventory policies. Consequently, this study offers useful algorithms and efficient inventory models for manufacturing sectors and suggests future research directions for the proposed work (Tyagi et al., 2023).

6. Conclusion

To conclude, the present study discusses about strengths, weaknesses of deterministic and stochastic model and applicability of major inventory models like vendor-managed inventory and Economic order quantity. The model can be evaluated for different types of parameters that include suitability, demand variability adaptability, implementation ease and cost efficiency for various industries. The review includes the contextual factors that enhances the performance of model like organizational structure, type of product and market dynamics. The model analyses provide insights with inventory strategy to enhance the competitiveness and operational efficiency. The findings of the study provide the real-world applications of the inventory models.

References

Vidal, G. H. (2023). Deterministic and stochastic inventory models in production systems: a review of the literature. *Process Integration and Optimization for Sustainability*, *7*(1), 29-50.

Antic, S., Djordjevic Milutinovic, L., & Lisec, A. (2022). Dynamic discrete inventory control model with deterministic and stochastic demand in pharmaceutical distribution. *Applied Sciences*, *12*(3), 1536.

Khedlekar, U. K., Kumar, L., & Keswani, M. (2023). A stochastic inventory model with price-sensitive demand, restricted shortage and promotional efforts. *Yugoslav Journal of Operations Research*, *33*(4), 613-642.

Jauhari, W. A., & Wangsa, I. D. (2022). A manufacturer-retailer inventory model with remanufacturing, stochastic demand, and green investments. *Process Integration and Optimization for Sustainability*, *6*(2), 253-273.

Nozari, H., Ghahremani-Nahr, J., & Szmelter-Jarosz, A. (2023). A multi-stage stochastic inventory management model for transport companies including several different transport modes. *International Journal of Management Science and Engineering Management*, *18*(2), 134-144.

Gupta, S., & Mishra, V. K. (2024). Multi-item stochastic inventory model for deteriorating items with power demand pattern under partial backlogging and joint replenishment. *Annals of Operations Research*, 1-29.

Waliv, R. H., Mishra, U., Garg, H., & Umap, H. P. (2020). A nonlinear programming approach to solve the stochastic multi-objective inventory model using the uncertain information. *Arabian journal for science and engineering*, *45*(8), 6963-6973.

Tai, P., Huyen, P., & Buddhakulsomsiri, J. (2021). A novel modeling approach for a capacitated (S, T) inventory system with backlog under stochastic discrete demand and lead time. *International Journal of Industrial Engineering Computations*, *12*(1), 1-14.

Canyakmaz, C., Özekici, S., & Karaesmen, F. (2019). An inventory model where customer demand is dependent on a stochastic price process. *International Journal of Production Economics*, *212*, 139-152.

Kumar, L., Ghoshi, P. S., Saxena, S., & Sharma, K. (2024). A COMPARATIVE STUDY OF INVENTORY MODELLING: DETERMINISTIC OVER STOCHASTIC APPROACH. *Reliability: Theory & Applications*, *19*(1 (77)), 804-818.

Öztürk, H. (2020). A deterministic production inventory model with defective items, imperfect rework process and shortages backordered. *International Journal of Operational Research*, *39*(2), 237-261.

Benkherouf, L., & Gilding, B. H. (2022). The nature of optimal policies for deterministic finite-horizon inventory models. *International Journal of Systems Science: Operations & Logistics*, *9*(1), 39-60.

Wei, L., Jasin, S., & Xin, L. (2021). On a deterministic approximation of inventory systems with sequential service-level constraints. *Operations Research*, *69*(4), 1057-1076.

Stopková, M., Stopka, O., & Ľupták, V. (2019). Inventory model design by implementing new parameters into the deterministic model objective function to streamline effectiveness indicators of the inventory management. *Sustainability*, *11*(15), 4175.

Aladwani, R. M., Benkherouf, L., & Almathkour, F. (2023). Optimal inventory policies for finite horizon deterministic inventory models for non-instantaneous deteriorating items and permissible-delay in payment. *International Journal of Systems Science: Operations & Logistics*, *10*(1), 2235268.

Adebayo, A., Daniel, I., & Oluwakemi, O. (2024, April). Dynamics of Finished Goods Inventory Control Framework: A Deterministic Request in Product Appropriation. In *Operations Research Forum* (Vol. 5, No. 2, p. 31). Cham: Springer International Publishing.

Alnowibet, K. A., Alrasheedi, A. F., & Alqahtani, F. S. (2022). Queuing models for analyzing the steady-state distribution of stochastic inventory systems with random lead time and impatient customers. *Processes*, *10*(4), 624.

Giri, S. K., Garai, T., Garg, H., & Islam, S. (2021). Possibilistic mean of generalized non-linear intuitionistic fuzzy number to solve a price and quality dependent demand multi-item inventory model. *Computational and applied Mathematics*, *40*(4), 110.

Ahmadini, A. A. H., Modibbo, U. M., Shaikh, A. A., & Ali, I. (2021). Multi-objective optimization modelling of sustainable green supply chain in inventory and production management. *Alexandria Engineering Journal*, *60*(6), 5129-5146.

Biuki, M., Kazemi, A., & Alinezhad, A. (2020). An integrated location-routing-inventory model for sustainable design of a perishable products supply chain network. *Journal of Cleaner Production*, *260*, 120842.

Shokouhifar, M., Sabbaghi, M. M., & Pilevari, N. (2021). Inventory management in blood supply chain considering fuzzy supply/demand uncertainties and lateral transshipment. *Transfusion and Apheresis Science*, *60*(3), 103103.

Maheshwari, S., Kausar, A., Hasan, A., & Jaggi, C. K. (2023). Sustainable inventory model for a three-layer supply chain using optimal waste management. *International Journal of System Assurance Engineering and Management*, *14*(Suppl 1), 216-235.

Modares, A., Farimani, N. M., & Emroozi, V. B. (2023). A vendor-managed inventory model based on optimal retailers selection and reliability of supply chain. *Journal of Industrial and Management Optimization*, *19*(5), 3075-3106.

Vaka, D. K. (2024). Integrating Inventory Management and Distribution: A Holistic Supply Chain Strategy. *the International Journal of Managing Value and Supply Chains*, *15*(2), 13-23.

Gayam, S. R., Yellu, R. R., & Thuniki, P. (2021). Optimizing Supply Chain Management through Artificial Intelligence: Techniques for Predictive Maintenance, Demand

Forecasting, and Inventory Optimization. *Journal of AI-Assisted Scientific Discovery*, *1*(1), 129-144.

Franco, C., & Alfonso-Lizarazo, E. (2020). Optimization under uncertainty of the pharmaceutical supply chain in hospitals. *Computers & Chemical Engineering*, *135*, 106689.

Tyagi, T., Kumar, S., Malik, A. K., & Vashisth, V. (2023). A novel neuro-optimization techniques for inventory models in manufacturing sectors. *Journal of Computational and Cognitive Engineering*, *2*(3), 204-209.