AI-Enabled Preservation Technology within Supply Chain Models

Ankit Kumari[1], Menaka[2]

[1]PhD Scholar, Department of Mathematics, School of Applied Sciences, OM Sterling Global University, Hisar, Haryana, India-125001
[2]Department of Mathematics, School of Applied Sciences, OM Sterling Global University, Hisar, Haryana, India-125001

Abstract
The integration of artificial intelligence (AI) methods into conservation technologies in supply chain frameworks. Preservation technologies are employed to uphold product quality, prolong shelf life, and minimize waste, particularly in sectors handling perishable items like food, pharmaceuticals, and agricultural goods. Conventional preservation techniques, though successful, frequently fall short in flexibility and efficiency within changing supply chain settings. Preservation technology is the key component of an inventory cycle for degradation. Thanks to its use, the quality and quantity of the products can be maintained, meaning that deterioration cannot initiate earlier, and if it does begin, it reduces. An intelligent production system incorporates energy expenses and various elements, including selling price, eco-friendliness, marketing, and others. Inventory management is the crucial phase of production oversight. Products consist of raw materials, tools, labor, finished items, packaged goods, and general supplies. Examining inventory issues of goods with storage techniques and needs is quite engaging for straightforward inventory management. This study seeks to introduce an additional aspect to the modeling of inventory management storage technologies under varying demand rates and transportation expenses. This approach seeks to create and outline product models for non-standard items catering to diverse needs and various actual combinations.

Keywords: Artificial Intelligence, Preservation Technology, Deterioration, Stock, Inventory Management, Production System, Optimal Quantity**.**

Introduction

The concept of inventory control was introduced by Haris Wilson in the year 1913 under the assumptions (i) demand of the production is constant, (ii) shortages are not permitted and (iii) the product has no deterioration effect. However, in reality every product loses their freshness and utility after certain time period. After that this effect is continued with the passing of time. This natural phenomenon is called deterioration. So, it has an impact in inventory analysis and it cannot be ignored. Ghare and Schrade first developed an inventory model with the assumption of constant deterioration. However, the deterioration rate is not always constant, it may vary. Emmons proposed an inventory model with variable deterioration with the help of two-parameter Weibull distribution. Preservation of a product is an important issue in the inventory control system. It prevents the deterioration effect of the products while these are stored in the warehouse/showroom. Considering deterioration effect of the product and preservation technology, an inventory model of non-instantaneous deteriorating items is developed with the demand dependent on the selling price of the product. Although the total cost may be increased, there are savings due to the decrease of deterioration items. There are two possible ways to applying preservation technology such as discrete type and continuous type. In discrete type, there may use different costs in a different interval of time based on behave of products condition, but in continuous type, there may be fixed cost throughout the inventory cycle. There will be no shortages, and customer demand will be fulfilled throughout the inventory cycle and obtain maximum profit under preservation technology. Now a day, maximum manufacturers apply this way to their business to make a smooth process. The fresh product manufacturing system plays a vital role in preserving the products and increasing their freshness period. For the other liquid daily necessary products such as milk, different medicines, different drinking liquids, etc., can be preserved by using such preservation technology cost until a certain period. Nowadays, preservation technology is more important for emergency cases to preserve such valuable life parts, essential for a hospitalized patient. Thus using preservation technology, our world, including every manufacturing system, can be forward in advance. For example, in our surroundings by different preservation techniques trying to prevent spoilage of many things. All types of items are preserved with a mixture of ice. Sometimes it is seen that different food items are kept in a jar, spices within a packet to preserve from outside weather, and others matter. It is known that from the history of past research, and improved hurdle technology for food preservation was introduced by Leistner (2000). A preservation technology based research model proposed by Hsu et al. (2010) and Dye (2013). The previous model of Dye (2013) was extended by Yang et al. (2015) by considering trade credit policy and dynamic programming problems. Through the extension of the previous model, Dye and Yang (2016) proposed a model by incorporating the replenishment policy and pricing strategy. A green label-based supply chain management of deteriorating items, in which investment for preservation technology makes the supply chain more profitable, was discussed by Saha et al. (2017). A comparative study of different food preservation techniques was presented by Atuonwu et al. (2018), in which greenhouse gas emission was considered. Ullah et al. (2019) introduced an integrated inventory model of deteriorating items, where preservation technology investment reduces the joint supply chain cost by more than 13%. A case study on real-life was discussed by Mohammadi et al. (2019) under the supply chain with preservation technology. An inventory model of deteriorating items with preservation strategy and partial backlogging was studied by Das et al. (2020). Saha et al. (2021) discussed a preservation technology-based inventory model of seasonable and fashionable items and was solved through flower pollination algorithm. Preservation technology investment-based supply chain model of deteriorating items considered.

 

Fig1: Different preservation method

Another motivating matter is the environmental issue. Green products or greening investment is the probable solution in these cases. The deteriorating items are another thinking matter. Although preservation technology can reduce it, transportation of deteriorated items from one to other supply chain members is challenging. Another motivating issue is the disposal of defective items. Rework of defective items can outline more profit. Besides remanufacturing of rework items with warranty and delay-in-payments facility is also a solution of defective items. Another problem which in general makes a critical situation for the production system is the out-of-control situation. Restoration policy and maintenance strategy may be the way of solution in this case. All these motivated ideas reflected through the different research article. Above all, the main issue of this portion is to find out the suitable way/outline through which an improves supply chain can built for the sustainable development of the society. Numerous manufacturing firms with broad product ranges typically employ product managers who oversee product sales. Efficient inventory control, involving the resolution of inventory inquiries across different sites, is essential for the firm's competitive achievement. Failing to move an item may result in delays in acquiring the needed item or equipment, whereas relocating all items in a location can incur significant expenses and create excess inventory. Managers frequently depend on mathematical models and computer systems created by mathematicians, operations researchers, and industrial engineers for product management and issue resolution. There are numerous models corresponding to the number of companies, as each model possesses unique standards and constraints. All businesses maintain inventory to serve their clients. Safeguarding a product is the priority of every business entity. This immediately harms the product, which can be kept in the showroom or storage area. The majority of inventory models are developed in the database according to a demand level. In reality, it is unrealistic to believe that the request is handled promptly. Experience indicates that superior quality products boost sales for customers. Nonetheless, for certain products sold, particularly items, the degree of usage is contingent upon the volume of goods sold. The cost of consumption will rise or fall based on the products accessible in the system. Sales at retail outlets are frequently connected to the variety of products offered, and it has been noted that the selection available in a store can draw in or motivate additional customers. These findings have prompted studies on modeling the phenomenon. Up to this point, numerous business professionals and physicians were not knowledgeable about this advantage. Earlier models presumed that storage expenses stayed the same during the inventory process. A smart production system with energy costs and different factors, such as selling price, green quality, advertisement, etc., are to be considered with the modelling. Machine breakdown and unusual energy consumption are ordinary matters in a long-run production process, which are huge problems for every smart production management. Through development investment and

improved technology, the failure rate was reduced here. The research also focused on the green supply chain management with waste reduction, which technique controls the market demand and variable production rate. Transportation through freezing preservation technology and remanufacturing considered. Through the disposal of the deteriorated products with the effects of service level for the lead time crashing and setup cost reduction are considered. Moreover, quality improvement and transportation discount policy helps the management through minimizing the systems total cost. Restoration techniques control the out-of-control situation, and maintenance policy reduces the machine failure rate. However, rework and warranty are also considered to attract the customer in the modern business strategy.
In supply chain modelling, AI-enhanced preservation technology can:

- **Monitor and predict product quality** using IoT sensors, computer vision, and predictive models.
- **Optimize inventory and logistics decisions** under uncertain demand and shelf-life constraints.
- **Enhance sustainability** by reducing spoilage, energy consumption, and costs.
- **Enable intelligent automation** in cold chain management and preservation processes.

Literature Review

Preservation of any product is a vital tool in meeting many people's daily needs in today's society. It is needed more in the case of perishable products but needed less preservation is required in other products. If there is no preservation, there will be a shortage of food and the high price of such foods. Preservation is mainly done through packaging, a freezing system, and any other processes. For the seasonal vegetable, fruit preservation is highly needed for the whole year supply. Besides the expiry-based items such as alcohol, milk, medicine, vaccine, baby foods, etc., preservation is needed in the supply for emergency cases. Due to preservation, investment quality and quantity of the products remain unchanged. It may be constant or variable. For the short-term business, constant preservation may be controlled, but there is a needed variable preservation investment for the long-term business. Besides, for the long-distance fresh products business there needed preservation technology within the caring container to control the quality of the product. All the members, including the producer, become more profitable through preservation technology investment. For example, where potatoes are cultivated, their farmers store potatoes in local cold storage after digging potatoes. In that case, it is possible to supply potatoes throughout the year, and the farmers highly profitable through the price of potatoes. It should be noted that potatoes do not stay in the open for long. There is much research based on preservation costs. Dye and Hsieh (2012) introduced preservation technology investment in a deteriorating item. The previous model extended by Dye and Yang (2016) through dynamic pricing strategy. Mishra et al. (2018) considered controllable deterioration through preservation technology investment. For deteriorating items, Singh et al. (2020) proposed the effects of preservation. Recently Saha et al. (2021) discussed the effects of preservation technology on flower pollination algorithm.
Preservation technology is an important factor to reduce the deterioration effect. Regarding this context, different business enterprises/organizations are bound to apply preservation technology in inventory control system. Hsu et al. (2010) first introduced the preservation technology concept in their work. They developed an inventory model under constant demand with the preservation technology. Hsieh & Dye (2012) analyzed the effect of preservation investment in a production inventory model. Dye & Hsieh (2013) derived a production model under time-dependent demand with controllable deterioration effect. Dye (2013) introduced the non-instantaneous deteriorated inventory model under preservation technology. Zhang et al. (2014) solved a deteriorating inventory model with preservation technology

under stock dependent demand. Yang et al. (2015) proposed a preservation inventory model under trade credit with deterioration effect. Zhang et al. (2016) developed an inventory model for the deteriorating item with preservation facility under common resource constraint. Mishra et al. (2017) presented a preservation inventory model underprice-dependent demand with shortage. Pal et al. (2013) and Shaikh et al. (2019) investigated preservation related inventory models for deteriorating item. Li et al. (2019) considered preservation technology for non-instantaneous deteriorating items. In the retail business, it is observed that the demand of an item is dependent on different factors. One such factor is the selling price of an item. Selling price of an item plays an important role in the demand of the product. In this context, Datta & Paul (2001) proposed a finite time horizon inventory model with the variable demand dependent on price and stock of the product. Teng & Chang (2005) solved a production inventory model under the price and stock dependent demand. Hou & Lin (2008) proposed an inventory model with the demand dependent on selling price and stock of the product. Yang et al. (2010) introduced the shortage concept and formulated an inventory model under price-dependent demand. Dye & Hsieh (2011) solved an inventory model with price dependent demand under a shortage. Agarwal et al. (2013) considered ramp type demand in deteriorating inventory model. Bhunia & Shaikh (2015) solved the trade credit inventory model with price dependent demand and deterioration.

In the last three years, many economists have discovered that in some stores, such as supermarkets, the products already sold there can affect the demand for products. Levin et al. (1972) pointed out that the availability of goods has a motivating effect on people's environment and that more goods in the store will make consumers buy more. Silver and Peterson (1985) pointed out that product sales tend to be directly related to product sales. However, significant analysis of this type means that retail stores will benefit more from higher demand and higher product. Therefore, one of the problems retailers face is the size of the refills and the length of the return cycle. But in real life, the damage is a lot. Perishable foods can be divided into two main categories. Class 1 includes materials that have infinite life and a low rate of damage during wear and tear, such as gasoline, wood, honey, alcohol, and power tools. The second category includes products with expiration dates, such as beverages, vegetables, canned goods, bread, butter, cosmetics, sugar, milk, and most medicinal products. Gupta and Vrat (1986) first developed an environmental consumption model to reduce costs, which assumes inventory- related consumption rates as a function of initial inventory. Padmanabhan and Vrat (1995) also propose a commodity model of perishable goods in which the selling price is dependent on the commodity. Suppose the selling price is a function of available inventory. Wu et al. (2006) provided an additional strategy for non-perishable items, including on-demand inventory and partial returns. Bai et al. (2016) proposed a supply chain model of deteriorating products with coordinating game strategy and revenue sharing contract. Banerjee and Agrwal (2017) studied an integrated type of inventory model of deteriorating products where demand depends on freshness quality and price. Ouaret et al. (2018) developed a replacement policy-based production manufacturing system of deteriorating items. Tiwari et al. (2019) discussed a green inventory model of deteriorating products in which reduction of carbon emission make the model more sustainable. Recently, Yang et al. (2020) presented inventory management of perishable items in which freshness-preservation effort control the deterioration smoothly.

Fig 2: Use of EPQ

Gupta et al. (2007) developed a genetic application to a market-oriented inventory model with short-run inventory cost and three asking prices tied to inventory. Maintenance is an important part of reducing the effects of wear. In this framework, legal entities/companies will continue to strive for innovation in management tools. Hsu et al. (2010) first delivered the Preservation technology idea in their work. They advanced a stock version under the constant demand for renovation generation. Hsieh & Dye (2012) analyzed the impact of renovation funding in a production stock version. Dye & Hsieh (2013) derived a production version under the time- established demand with a controllable deterioration impact. Dye (2013) delivered the non- immediately the deteriorated stock version under renovation generation. Zhang et al. (2014) solved a deteriorating stock version with renovation generation under the stock-established demand. Yang et al. (2015) proposed a renovation stock version under change credit score with a deterioration impact. Zhang et al. (2016) advanced a stock version for the deteriorating item with a renovation facility under not unusual place aid constraints. In any business, inventory management is now considered a very important part in the market. Therefore, how to manage it and how much to produce and supply according to demand play an important role in this 20th century. Therefore, inventory issues are starting to be studied much more than before. Inventories are stocks of raw materials and finished products. Analyzing inventory issues can minimize the cost and time associated with inventory. There are two types of material on the market. One has damage, loss, damage or decay while the other does not. Items such as radioactive materials, grains, fashion items, medicines, etc. have a limited lifespan, while items such as electronics, steel, wood, etc. have a long lifespan. Deterioration affects stocks and increases stock values. An appropriate inventory model must be formulated to bring the cost of inventory to an optimal level. For a long time, researchers have been trying to get an inventory model that can meet real-world needs. They have solved many stock issues. The issues relate to the different types of demand in the market, the type of productivity of the business organization, the finite lifespan of the product, the existence of defective production units, tolerance for delays or shortages, overdue, etc. Researchers usually use linear, quadratic, trapezoidal, exponential, time dependent, stochastic dependent, level or stock dependent, price dependent etc. They develop different inventory models by focusing on demand patterns that can be given all the limitations, there are two types of models in this area: by design, one is fixed demand and lead time-based decision making; the other is stochastic or probabilistic, involving different needs and lead times. In the literature review, inventory models with decision- making needs were discussed. Determining the Economic Order Quantity (EOQ) is one of the main factors in creating an inventory model. Replacing cost can be expressed as a variable equation that includes factors such as demand, equipment, production cost, lead-time, and other variables. These models help identify the best products, reorder content, and manage out-of-stock products and performance.

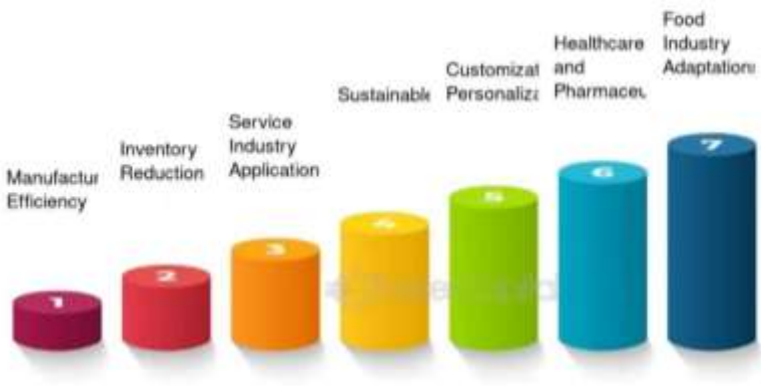

Fig 3: EPQ's Impact on Industry

Mishra et al. (2017) presents refurbished stock options influenced by low demand influenced by pricing. Additionally, Parr et al. (2013) and Sheikh et al. (2019) explored the adverse impacts linked to fashion items. Dhaka et al. (2017) created an inventory model for the best pricing and ordering strategies considering two-tier trade credits. Lee et al. (2019) assessed the retrofitting process for unexpectedly faulty products. Recent developments in production have minimized losses through inventory management strategies. Gupta et al. (2013) indicated that the suggested quality decision for assessing product quality is the required stock level for the product that does not spoil instantly. The effect of effective decision making in product-oriented goods (Kumar et al. 2016, 2017, 2019; Mathur et al. 2019; Malik 2016, 2017, 2018; Singh 2008, 2009, 2010); while analyzing the information. Malik et al. (2012) and Yadav and Malik (2014) address optimization in inventory management. Among these approaches, stock-dependent demand, linear demand, quadratic demand, partial backlogging, two warehouses, non-instantaneous, and uncertainty are commonly utilized in inventory management systems (Kumar et al. 2017, 2022; Malik et al. 2013, up to 2021a, 2021b; Sharma et al. 2013, 2022a, 2022b; Verma et al. 2022; Yadav et al. 2022a, 2022b; Singh and Malik 2009, 2010a, 2010b; Singh et al. 2011a, 2011b, 2014a, 2014b; Tyagi et al. 2022a, 2022b; Vashisth et al. 2016). Creating a suitable inventory model amid uncertainty is quite challenging because of market economy fluctuations and unpredictable consumer demand. To address these challenges, a food production model incorporating preservation technology was created amid uncertain risks, utilizing a parametric methodology and interval mathematics.

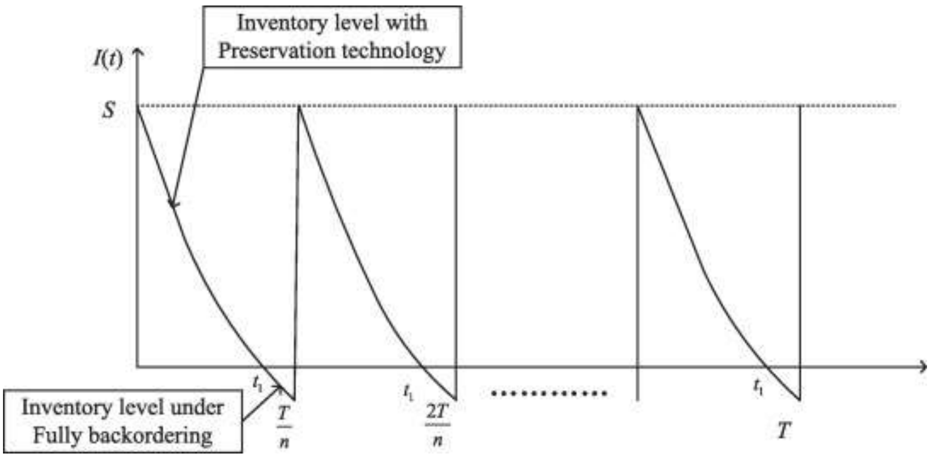

Fig 4: Effect of Preservation Technology in Inventory

The problem of commercial organizations getting the best products is especially important for food and pharmaceutical companies. The design of preservation technology with inventory system was also addressed by He and Huang (2013); Mishra (2013); Singh et al. (2016); Khanna (2020); Das et al. (2020). In an inventory system, generally three types of cost carrying, shortage and replenishing are significant and control by the right authority. These three types of costs are generally closely related to each other. When one cost is decreased or increased one of the other two costs and sometimes even both may increase there is thus the problem of controlling the cost so that their sum will be lowest. It is a challenging question to control the inventory. Many concepts and techniques were proposed by mathematicians for controlling the inventory effectively. These advantages serve to counterbalance the drawbacks of an imperfect in-house production system (Haq et al., 2023). Outsourcing provides a heightened level of adaptability, empowering the dual-channel retailers to respond to shifting consumer demands by easily adjusting production levels in collaboration with their outsourced partners. Such flexibility is indispensable for effectively manoeuvring within the ever-evolving landscape of the online marketplace (Lu and Yi, 2023). By delegating a portion of production to a partner, the manufacturer can potentially mitigate the impact of defects on their own output. This can lead to a more consistent supply of high-quality products for both online and offline stores (Yang et al., 2024a). Additionally, outsourcing allows the manufacturer to leverage the expertise or lower production costs of their partner, potentially improving overall efficiency and cost-competitiveness. This is particularly relevant because managing fluctuations in demand due to potential production issues becomes easier when some production capacity lies outside the company (Guchhait and Sarkar, 2024). However, the decision to outsource requires careful consideration of factors like finding a reliable partner, potential quality control challenges, and the impact on profit margins.

AI-Enabled Preservation Technology

Preservation technology in supply chains focuses on **maintaining product quality, extending shelf life, and minimizing losses** of perishable or sensitive goods such as food, pharmaceuticals, and agricultural products. When combined with **Artificial Intelligence (AI)**, these technologies become more **intelligent, adaptive, and predictive**, offering real-time insights and automated decision-making.

1. IoT and Sensor-Based Monitoring

Smart sensors (temperature, humidity, gas composition, vibration) monitor storage and transportation conditions. AI algorithms process sensor data to detect anomalies, predict spoilage, and adjust preservation parameters in real time.

2. Machine Learning for Shelf-Life Prediction

ML models analyze historical data on product quality, demand, and environmental conditions.
Predicts **remaining shelf life** and suggests optimal routing, storage, or replenishment.

3. Computer Vision & Image Processing

Cameras and AI-based vision systems assess freshness, ripeness, or defects in perishable goods.
Automates quality control at warehouses, retail outlets, and packaging facilities.

4. Optimization & Decision Support

AI-powered optimization models help schedule production, manage inventories, and design cold chain logistics. Preservation decisions are integrated into **supply chain models**, reducing cost, waste, and environmental impact.

5. Robotics and Automation

AI-controlled robotics manage handling, packaging, and sorting of sensitive items. Ensures minimal human error and contamination risk during preservation.

6. Blockchain with AI for Traceability

Ensures transparency of preserved goods throughout the supply chain. AI enhances blockchain records by verifying product condition and predicting risks.

Benefits of AI-Enabled Preservation Technology

- **Reduced spoilage & waste** through predictive preservation.
- **Improved product quality & safety** in food and pharmaceutical supply chains.
- **Cost optimization** in logistics, storage, and inventory.
- **Sustainable supply chains** with reduced energy consumption and carbon emissions.
- **Resilience under uncertainty**, supporting real-time adaptive decision-making.

Conclusion

AI-enabled preservation technology is transforming traditional supply chain models by introducing intelligence, adaptability, and predictive capability into the management of perishable and sensitive goods. By integrating tools such as machine learning, IoT sensors, computer vision, and optimization algorithms, supply chains can not only extend product shelf life but also enhance real-time decision-making, reduce wastage, and improve sustainability. This fusion of AI with preservation practices ensures better quality monitoring, efficient cold chain management, and resilient inventory systems under uncertain demand and environmental conditions. Ultimately, AI-driven preservation technology represents a vital step toward building **smart, sustainable, and future-ready supply chains** that balance economic performance with environmental responsibility. The preservation method reduced waste by reducing the deterioration rate and extended lifespan by maintaining the quality and quantity of products. Such a system also controlled environmental degradation. Improper disposal of products increased pollution, which was another primary cause of environmental atrophy. The effects of preservation and variable production in a two-echelon supply chain management. Along with cost minimization, which is the primary concern of the industry, a method to reduce waste is provided. The use of the preservation method extended the life of deteriorated green products and reduced the number of products for disposal. The results showed that the variable production technique enables better cost minimization compared to constant production, while preservation reduced the quantity of waste. Quality concerns were addressed via the use of a freezing system during the transportation of perishable products. Additionally, the waste from supply chain management can be used as raw materials for another supply chain management, called the secondary supply chain management. The energy required for the entire supply chain can be calculated with renewable energy resources for the traveling time. The transportation freezing system is an ideal method for maintaining the quality and lifespan of perishable products over long transport distances. The remanufacturing of defective products positively affects the socio-economic stability of the manufacturer. Environmental benefits are also enabled on both the manufacturing and retail end. It may be noted that the preservation of products affects market demand because the specified model ensures suitable products availability.

Future Scope

The integration of AI into preservation technology within supply chain models is still evolving and presents vast opportunities for future development:

1. **Advanced Predictive Modelling**
   - Development of more accurate AI models to predict shelf life, spoilage, and demand under uncertain and dynamic environments.
   - Use of hybrid AI approaches combining machine learning, deep learning, and fuzzy logic.
2. **Real-Time Adaptive Supply Chains**
   - AI-driven systems that continuously learn and adjust preservation conditions in warehouses, cold chains, and retail outlets.
   - Greater use of **digital twins** to simulate and optimize preservation strategies.
3. **Integration with Emerging Technologies**
   - Fusion of **IoT, blockchain, and AI** for end-to-end visibility, traceability, and trust in preserved goods.
   - Adoption of **edge computing** for faster, decentralized decision-making in preservation.
4. **Sustainable Preservation Systems**
   - AI-based optimization of energy use in cold chains to minimize carbon emissions.
   - Smart packaging with embedded sensors and AI analytics for eco-friendly monitoring.
5. **Expansion Across Industries**
   - Wider application in pharmaceuticals, healthcare (e.g., vaccines, biologics), agriculture, and e-commerce.
   - Customized AI models for small and medium enterprises (SMEs) to improve accessibility.
6. **Human-AI Collaboration**
   - AI decision-support tools for managers to balance cost, quality, and sustainability.
   - Training supply chain professionals to effectively adopt and integrate AI technologies.
7. **Challenges and Research Directions**
   - Addressing data privacy, cybersecurity, and interoperability issues in AI-enabled systems.
   - Developing cost-effective AI solutions to ensure scalability across global supply chains.

Reference

1. A.A. Shaikh, G.C. Panda, S. Sahu, A.K. Das (2019). Economic order quantity model for deteriorating item with preservation technology in time dependent demand with partial backlogging and trade credit, Int. J. Logistics Syst. Manage. 32 (1), 1–24.

2. B. Pal, S.S. Sana, K. Chaudhuri, (2013). Three stage trade credit policy in a three-layer supply chain–a production-inventory model, Int. J. Syst. Sci. 45 (9), 1844–1868.
3. C.T. Yang, C.Y. Dye, J.F. Ding, (2015). Optimal dynamic trade credit and preservation technology allocation for a deteriorating inventory model, Comput. Ind. Eng. 87, 356–369.
4. C.Y. Dye (2013). The effect of preservation technology investment on a non-instantaneous deteriorating inventory model, Omega 41 (5), 872–880.
5. Das, S. C., Zidan, A. M., Manna, A. K., Shaikh, A. A., & Bhunia, A. K. (2020). An application of preservation technology in inventory control system with price dependent demand and partial backlogging. Alexandria Engineering Journal, 59(3), 1359-1369.
6. Dye, C. Y., & Hsieh, T. P. (2012). An optimal replenishment policy for deteriorating items with effective investment in preservation technology. European Journal of Operational Research, 218(1), 106-112.
7. G. Li, X. He, J. Zhou, H. Wu, (2019). Pricing, replenishment and preservation technology investment decisions for non-instantaneous deteriorating items, Omega 84, 114–126.
8. Gupta, K. K., Sharma, A., Singh, P. R., Malik, A. K. (2013). Optimal ordering policy for stock-dependent demand inventory model with non-instantaneous deteriorating items. International Journal of Soft Computing and Engineering, 3(1), 279-281.
9. Gupta, R., Vrat, P., (1986). Inventory models for stock-dependent consumption rate. Opsearch 23, 19–24.
10. He, Y., & Huang, H. (2013). Optimizing inventory and pricing policy for seasonal deteriorating products with preservation technology investment. Journal of Industrial engineering, 2013.
11. J. Zhang, Q. Wei, Q. Zhang, W. Tang (2016). Pricing, service and preservation technology investments policy for deteriorating items under common resource constraints, Comput. Ind. Eng. 95, 1–9.
12. J. Zhang, Z. Bai, W. Tang (2014). Optimal pricing policy for deteriorating items with preservation technology investment, J. Indus. Manage. Optimize. 10 (4), 1261–1277.
13. Khanna, A., Pritam, P., & Jaggi, C. K. (2020). Optimizing preservation strategies for deteriorating items with time-varying holding cost and stock-dependent demand. Yugoslav Journal of Operations Research, 30(2), 237-250.
14. Kumar, Pushpendra, Purvi J. Naik, and A. K. Malik. (2022). An Improved Inventory Model for Decaying Items with Quadratic Demand and Trade Credits. *Forest Chemicals Review*. 1848-1857.
15. Kumar, S., Chakraborty, D., Malik, A. K. (2017). A Two Warehouse Inventory Model with Stock-Dependent Demand and variable deterioration rate. International Journal of Future Revolution in Computer Science & Communication Engineering, 3(9), 20-24.
16. Kumar, S., Malik, A. K., Sharma, A., Yadav, S. K., Singh, Y. (2016). An inventory model with linear holding cost and stock-dependent demand for non-instantaneous deteriorating items. In AIP Conference Proceedings (Vol. 1715, No. 1, p. 020058). AIP Publishing LLC.
17. Kumar, S., Singh, Y., Malik, A. K. (2017). An Inventory Model for both Variable Holding and Sales Revenue Cost. Asian J. Management. 8(4):1111-1114.
18. Kumar, S., Soni, R., Malik, A. K. (2019). Variable demand rate and sales revenue cost inventory model for non-instantaneous decaying items with maximum lifetime. International Journal of Engineering & Science Research, 9(2), 52-57.
19. Kun-Shan Wu, Liang-Yuh Ouyang, Chih-Te Yang, (2006). An optimal replenishment policy for non-

instantaneous deteriorating items with stock dependent demand and partial backlogging. International Journal of production Economics, vol. 101, 2, pages 369-384.
20. Malik, A. K. and Singh, Y. (2013). A fuzzy mixture two warehouse inventory model with linear demand. International Journal of Application or Innovation in Engineering and Management. 2(2): 180-186.
21. Malik, A. K. and Singh, Y. (2011a). An inventory model for deteriorating items with soft computing techniques and variable demand. International Journal of Soft Computing and Engineering. 1(5): 317-321.
22. Malik, A. K., and Sanjay Kumar. (2011b). Two Warehouses Inventory Model with Multi-Variate Demand Replenishment Cycles and Inflation. *International Journal of Physical Sciences.* 23(3), 847-854.
23. Malik, A. K., and Yashveer Singh. (2011c). An Inventory Model for Deterioration items with Variable Demand and Partial Backlogging. *International Journal of Physical Sciences*. 23(2), 563-568.
24. Malik, A. K., Chakraborty, D., Bansal, K. K., Kumar, S. (2017). Inventory Model with Quadratic Demand under the Two Warehouse Management System. International Journal of Engineering and Technology. 9(3): 2299-2303.
25. Malik, A. K., Chakraborty, D., Kumar, S. (2017b). Quadratic Demand based Inventory Model with Shortages and Two Storage Capacities System. Research J. Engineering and Tech. 8(3): 213-218.
26. Malik, A. K., Sharma, M., Tyagi, T., Kumar, S., Naik, P. J., & Kumar, P. (2022). Effect of Uncertainty in Optimal Inventory Policy for Manufacturing Products. International Journal of Intelligent Systems and Applications in Engineering. 10(1s), 102-110.
27. Malik, A. K., Shekhar, C., Vashisth, V., Chaudhary, A. K., Singh, S. R. (2016a). Sensitivity analysis of an inventory model with non-instantaneous and time-varying deteriorating Items. In AIP Conference Proceedings. 1715(1): 020059.
28. Malik, A. K., Singh, P. R., Tomar, A., Kumar, S., & Yadav, S. K. (2016b). Analysis of an inventory model for both linearly decreasing demand and holding cost. In *AIP Conference Proceedings* (Vol. 1715, No. 1). AIP Publishing.
29. Malik, A. K., Singh, S. R., Gupta, C. B. (2008). An inventory model for deteriorating items under FIFO dispatching policy with two warehouse and time dependent demand. Ganita Sandesh. 22(1), 47-62.
30. Malik, A. K., Singh, Y., Gupta, S. K. (2012). A fuzzy based two warehouses inventory model for deteriorating items. International Journal of Soft Computing and Engineering. 2(2), 188-192.
31. Malik, A. K., Tarannum Bano, Mahesh Kumar Pandey, and Kapil Kumar Bansal. (2021). Inflation based Inventory model among non-instantaneous decaying items with linear demand rate. *Annals of Optimization Theory and Practice*.
32. Malik, A. K., Tomar, A., & Chakraborty, D. (2016). Mathematical Modelling of an inventory model with linear decreasing holding cost and stock dependent demand rate. International Transactions in Mathematical Sciences and Computers, 9, 97-104.
33. Malik, A. K., Vedi, P., and Kumar, S. (2018). An inventory model with time varying demand for non-instantaneous deteriorating items with maximum life time. International Journal of Applied Engineering Research, 13(9), 7162-7167.
34. Malik, A. K., Yadav, S. K., & Yadav, S. R. (2012). Optimization Techniques, I. K International Pub. Pvt. Ltd., New Delhi.

35. Malik, A.K. and Garg, H. (2021). An Improved Fuzzy Inventory Model Under Two Warehouses. Journal of Artificial Intelligence and Systems. 115–129. https://doi.org/10.33969/AIS.2021.31008.
36. Malik, A.K. and Sharma A. (2011d). An Inventory Model for Deteriorating Items with Multi- Variate Demand and Partial Backlogging Under Inflation, International Journal of Mathematical Sciences. 10(3-4): 315-321.
37. Malik, A.K., Singh, A., Jit, S., Garg. C.P. (2010). Supply Chain Management: An Overview. International Journal of Logistics and Supply Chain Management. 2(2): 97-101.
38. Malik, Ajit, Vinod Kumar, and A. K. Malik.(2016). Importance of operations research in higher education. *International Journal of Operations Research and Optimization*. 7(1- 2), 35-40.
39. Mathur, P., Malik, A. K., & Kumar, S. (2019). An inventory model with variable demand for non-instantaneous deteriorating products under the permissible delay in payments. In IOP Conference Series: Materials Science and Engineering. Vol. 594. IOP Publishing.
40. Mishra, V. K. (2013). Deteriorating inventory model using preservation technology with salvage value and shortages. Advances in Production Engineering and Management, 8(3), 185-192.
41. P.H. Hsu, H.M. Wee, H.M. Teng (2010). Preservation technology investment for deteriorating inventory, Int. J. Prod. Econ. 124 (2), 388–394.
42. Sharma, A., Gupta, K. K., Malik, A. K. (2013). Non-Instantaneous Deterioration Inventory Model with inflation and stock-dependent demand. International Journal of Computer Applications. 67(25): 6-9.
43. Sharma, A., Singh, C., Verma, P., & Malik, A. K. (2022). Flexible Inventory System of Imperfect Production under Deterioration and Inflation. *Yugoslav Journal of Operations Research*. *32*(4), 515-528.
44. Sharma, Archana, and A. K. Malik. (2022). Profit-Maximization Inventory Model with Stock-Dependent Demand. In *Applications of Advanced Optimization Techniques in Industrial Engineering*, pp. 191-204. CRC Press.
45. Singh, S. R. and Malik, A. K. (2008). Effect of inflation on two warehouse production inventory systems with exponential demand and variable deterioration. International Journal of Mathematical and Applications, 2(1-2), 141-149.
46. Singh, S. R. and Malik, A. K. (2009). Two warehouses model with inflation induced demand under the credit period. International Journal of Applied Mathematical Analysis and Applications, 4(1), 59-70.
47. Singh, S. R. and Malik, A. K. (2010). Inventory system for decaying items with variable holding cost and two shops, International Journal of Mathematical Sciences. 9(3-4): 489- 511.
48. Singh, S. R. and Malik, A. K. (2009). Two warehouses model with inflation induced demand under the credit period. International Journal of Applied Mathematical Analysis and Applications. 4(1): 59-70.
49. Singh, S. R., & Malik, A. K. (2010). Optimal ordering policy with linear deterioration, exponential demand and two storage capacity. International Journal of Mathematical Sciences, 9(3-4), 513-528.
50. Singh, S. R., A. K. Malik, and S. K. Gupta. (2011). Two warehouses inventory model with partial backordering and multi-variate demand under inflation. *International Journal of Operations Research and Optimization*. 2(2), 371-384.
51. Vashisth, V., Soni, R., Jakhar, R., Sihag, D., & Malik, A. K. (2016). A two warehouse inventory model with quadratic decreasing demand and time dependent holding cost. In *AIP Conference Proceedings.* Vol. 1715(1).

52. Vashisth, V., Tomar, A., Chandra, S., Malik, A. K. (2016). A trade credit inventory model with multivariate demand for non-instantaneous decaying products. Indian Journal of Science and Technology, 9(15), 1-6.
53. Vashisth, V., Tomar, A., Soni, R., Malik, A. K. (2015). An inventory model for maximum life time products under the Price and Stock Dependent Demand Rate. International Journal of Computer Applications, 132(15), 32-36.
54. Verma, P., Chaturvedi, B. K., & Malik, A. K. (2022). Comprehensive Analysis and Review of Particle Swarm Optimization Techniques and Inventory System, International Journal on Future Revolution in Computer Science & Communication Engineering. 8(3), 111- 115.
55. Yadav, S. R., & Malik, A. K. (2014). Operations research. Oxford University Press.
56. Yadav, V., Chaturvedi, B. K., & Malik, A. K. (2022a). Advantages of fuzzy techniques and applications in inventory control. International Journal on Recent Trends in Life Science and Mathematics. 9(3), 09-13.
57. Yadav, V., Chaturvedi, B. K., & Malik, A. K.(2022b). Development of Fuzzy Inventory Model under Decreasing Demand and increasing Deterioration Rate, International Journal on Future Revolution in Computer Science & Communication Engineering. 8(4), 1-8.