Scalable Computing: Practice and Experience, ISSN 1895-1767, http://www.scpe.org
 Volume 26, Issues 1, pp. 212–219, DOI 10.12694/scpe.v26i1.3536

DEVELOPMENT AND APPLICATION OF SPORADIC MATERIAL INVENTORY OPTIMIZATION MANAGEMENT SYSTEM BASED ON ARTIFICIAL INTELLIGENCE

QIAN LI*, WENJUN HOU†, YATONG WU‡, YAQI HOU§, AND JIAN ZHU¶

Abstract. This paper introduces the overall framework of the intelligent electrical sporadic materials management system based on the ubiquitous Internet of Things. The system includes storage equipment and an intelligent management terminal. It makes optimal design for storage equipment and intelligent management terminals. The dynamic modeling of a three-layer supply chain system of power materials is constructed and composed of manufacturers, suppliers, and raw materials. The inventory control strategy of each link in the supply chain of power materials under different cooperation levels is studied by introducing the corresponding adjustment variables. Through the experiment and analysis of the system, it is proved that the system has good performance in label management, resource management, inventory management, disposal management, system management and essential management. The number of concurrent users, response speed, stability and other aspects of the system are excellent. The database is complete, independent, and secure. And the data is objectively reasonable and repairable. The system can lay a specific technical foundation for intelligent management of electrical sporadic materials.

Key words: Artificial intelligence; Power material optimization; Inventory optimization; Power material supply chain

1. Introduction. The auxiliary products produced by State Grid Power Company have a lot of uncertainties (such as great demand and large randomness). However, the traditional power supply chain information transmission system is subject to the lagging development of science and technology and the lack of effective control measures, resulting in high internal information concentration and imperfect information transmission mechanisms between different levels. It was found that due to insufficient information sharing and a slow interaction rate among enterprises at each link in the supply chain, information transmission between all links in the network will be significantly affected. Due to the lack of adequate information disclosure, the overall decision-making efficiency and effect of the whole supply chain are greatly restricted. Using new scientific and technological means is essential to effectively manage the existing supply chain and inventory of power materials. Literature [1] builds a supply chain management system based on blockchain, applies this system to the automotive industry and achieves an excellent win-win situation. Literature [2] uses the blockchain method to build a vehicle supply chain traceability system, which effectively alleviates the lack of credit among enterprises in all aspects of the vehicle supply chain. The system improves the security and traceability of vehicle information. Literature [3] introduced blockchain technology in the manufacturing industry and established the concept of "sharing culture" among enterprises, thus effectively improving the overall service quality of the manufacturing industry. Literature [4] argues that blockchain technology can generate three kinds of value: sharing, security, and smart contracts. These three features are embodied in the supply chain as encryption, consensus mechanisms, and smart contracts. Literature [5] introduced blockchain technology in the production process of dairy products to build distributed transaction records. The system can accurately track important information throughout the supply chain. This project intends to study the intelligent inventory management system of electrical sporadic materials in the ubiquitous Internet of Things environment, aiming to achieve the purpose of interconnection, ubiquitous visualization and intelligent management of electrical sporadic materials.

*State Grid Shanxi Electric Power Company Materials Branch, Taiyuan, Shanxi, China, 030021 (Corresponding author, 15333662419@163.com)
†State Grid Shanxi Electric Power Company Materials Branch, Taiyuan, Shanxi, China, 030021
‡State Grid Shanxi Electric Power Company Materials Branch, Taiyuan, Shanxi, China, 030021
§State Grid Shanxi Electric Power Company Materials Branch, Taiyuan, Shanxi, China, 030021
¶State Grid Shanxi Electric Power Company Materials Branch, Taiyuan, Shanxi, China, 030021

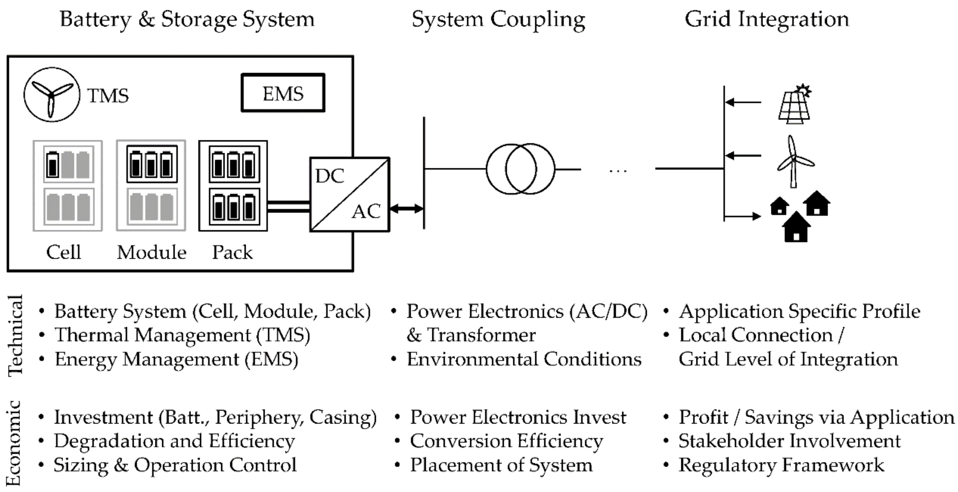

Fig. 2.1: Physical architecture of the electrical sporadic materials inventory management system.

2. Design of optimization management system for electric sporadic materials inventory.

2.1. System Architecture. The physical architecture of the intelligent management system for electric sporadic materials is shown in Figure 2.1 (the picture is quoted in Energies 2017, 10(12), 2107). Storage devices store waste power and waste materials. A load cell is arranged on each pad of the storage device. An intelligent management terminal is in the middle, under the tool [6]. The weighing sensor transmits the weight signal of the electric power device to the intelligent management terminal through the junction box. The intelligent management terminal uses 4 G/5 GNB-not to transmit the weight, position, height and other information to the intelligent management system [7]. Electrical sporadic materials are an intelligent management system that stores and transports waste materials for monitoring.

2.2. Optimal design of transportation and storage devices. Firstly, the whole system is optimized. The aim is to reduce its quality. The original half-fan door is transformed into a one-type door, which can effectively improve power materials' loading and unloading efficiency [8]. The lock structure has been improved to reduce the time required for unlocking and locking. The weighing part on the gate is combined with the whole gate by mounting the weighing element on each base plate. The weight of loading and unloading equipment is significantly reduced, and the total amount of stored electrical energy is increased.

2.3. Optimization design of intelligent management terminal. Information such as the location, quality, elevation and production process of electric power materials are stored intelligently and uploaded to the intelligent management platform of electric power materials [9]. The operation status of storage and transportation equipment is monitored, and parameters are set by using the human-machine interface. It is the central link to the whole process of monitoring and managing power generation equipment. The system comprises weighing, positioning, communication, and power supply modules. The modular architecture allows for easy maintenance and updates. This system separates weighing and other functional modules and the weighing sensor and intelligent management terminal are connected. The weighing sensor is connected to the terminal box, and the terminal box does not need to be opened when the weighing sensor is replaced to facilitate the installation, use, maintenance and update of the weighing sensor [10]. In addition, the spacing of each weighing element also reserves sufficient margin. Each weighing element carries about 10 t, which can ensure the quality of carrying electric energy materials. In the weighing process, the intelligent algorithm directly displays the necessary power materials in the storage and transportation unit on the web page.

Unlike the conventional single-frequency positioning method, the positioning module uses the L1+L5 frequency band. The L5 band has a high signal coding rate. The dual frequency band can effectively suppress the position deviation caused by the atmospheric ionosphere and significantly improve the position accuracy of

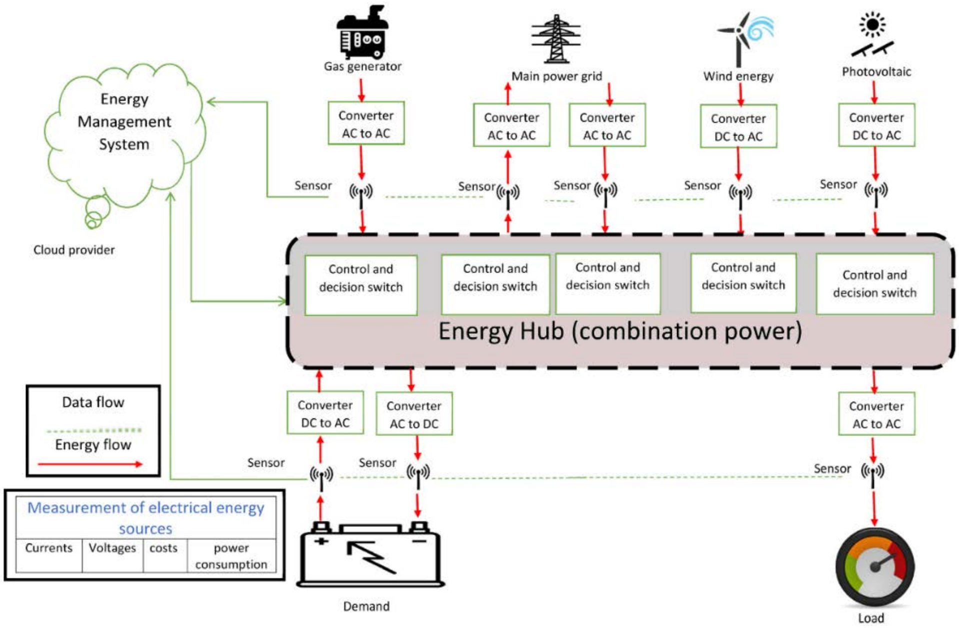

Fig. 2.2: Structure of intelligent power material management system based on ubiquitous Internet of Things.

the satellite. Intelligent management terminals can reach an accuracy of 3-5 meters in open areas. The relative height of the box is calculated by using the difference of air pressure in the height measurement to calculate the floor where the box is located accurately. The intelligent management terminal retains an upgradeable test interface, built-in RS-485, I/O and other ports for easy plugging and maintenance [11]. The 5G Internet of Things adopted in this paper has the characteristics of low power consumption and high anti-interference ability.

The power module uses a safe battery, which can increase the battery's capacity without increasing the housing size [12]. In the process of use, if there is an abnormal phenomenon, the system will send an email to remind the user. LCC batteries have a wide operating temperature range compared to nickel-chromium and lithium batteries.This battery will not spontaneously ignite even if a puncture occurs and charges faster.

2.4. Realization of service functions of the system. The platform can control the state of the whole process, analyze the whole data and make intelligent decisions [13]. The system is divided into three levels: data input layer, platform application layer and background management layer. Figure 2.2 shows the structure of the intelligent management system for electric power materials (the picture is quoted in Appl. Sci.2021, 11(21), 9820).

The core of the power materials management system is to input and manage the electronic label of power materials. The intelligent management process of resources, inventory and processing is realized [14]. Material management is mainly used to manage warehouse resources, such as warehouse number, location, automatic distribution, etc. Inventory management includes inventory count, inquiry, inventory count, warehouse capacity analysis, monthly inventory utilization, storage season and seasonal analysis, etc. Disposal management includes disposal method input, time reminder, plan formulation, approval, and early warning. The parameter setting layer includes the system management and essential management functions. These include name/number, role/position, data/function authorization, and system operation records. Essential management includes the basic functions of warehousing management, such as environmental parameter setting, purchase requirements management, warehousing rules setting, etc. The module also provides supplier/carrier management and transfer document management functions.

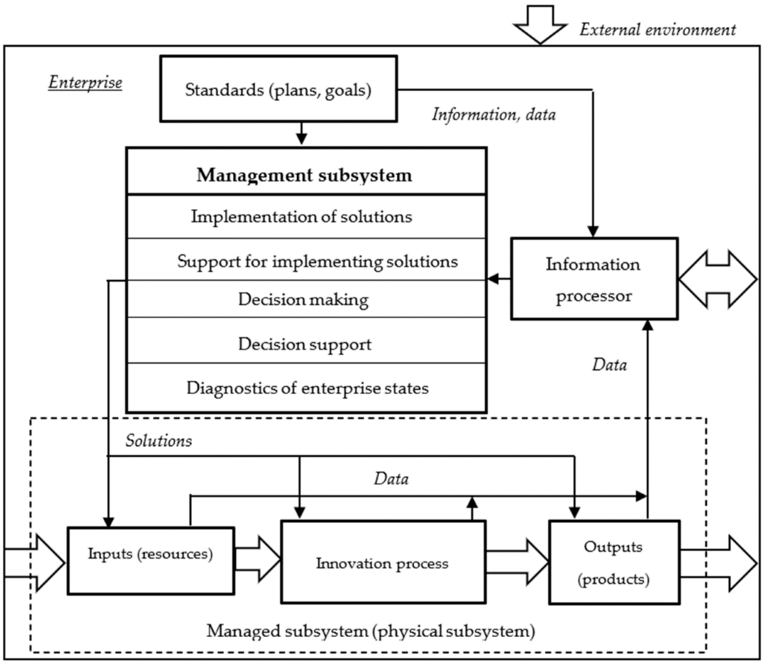

Fig. 2.3: Improved business process for intelligent management of power materials.

2.5. Business process optimization. The steps are the followings:

1. Change the traditional telephone booking mode and use the intelligent power supply equipment management platform to achieve booking.
2. The manually registered electric energy materials in the warehouse are reformed, and the intelligent management terminal is used to input and store electric energy materials.
3. Change the traditional warehouse and construction worker measurement modes and realize the automatic measurement by transportation unit measurement. The data is transmitted to the system through the intelligent management terminal and verified by the system.
4. The warehouse manager's location assignment mode is improved to automatically configure the location according to the optimal algorithm of the location allocation.
5. Change the method of manual inventory of electrical energy materials.

The system provides intelligent decision support for the disposal of power supplies, the optimal allocation of cargo locations, the inventory check of power supplies and other work.

3. Supply chain inventory management based on block database model. If there is no complete collaboration in the block-based database model, and only their inventory costs are shared, they will aim to optimize their inventory and make production and order forecasts. Let the quantity demanded $K(\alpha \leq K \leq \beta)$ be random and equally distributed. So now people have the distribution function $G(K) = \frac{K-\alpha}{\beta-\alpha}$ and the probability density $g(x) = \frac{1}{\beta-\alpha}$, so $\alpha = v - \sqrt{3}\varepsilon, \beta = v + \sqrt{3}\varepsilon$. The expected value is $v = \frac{\alpha+\beta}{2}$ and the standard deviation is $\varepsilon = \sqrt{\frac{(\beta-\alpha)^2}{12}}$. Table 3.1 lists the relevant variables and explanations.

3.1. Optimization of material platform orders. The material platform makes ordering decisions based on demand information shared by the various demand parties in the modular database [15]. The formula for calculating the inventory cost of the material platform can be obtained:

$$W_1(C_s) = Y_w \int_{Q_s}^{\infty} (K - Q_s)\, g_1(K)dx + C_s \int_0^{Q_s} (Q_s - K)\, g_1(K)dx + Y_s Q_s$$

Table 3.1: *Variables and Definitions.*

Variable	Paraphrase
C_m	Unit price of producer's inventory
C_n	Price of supplier's inventory
C_r	Material platform unit inventory cost
Q_m	Producer's output
Q_n	Quantity ordered by supplier
Q_r	Quantity ordered by material platform
P_m	Manufacturer's manufacturing cost per product
P_n	Supplier's unit price
P_r	Unit price of material platform
P_w	Unit price of material platform
C_z	The unit price of supply chain inventory
E	Total inventory

Taking the derivative of Q_s in formula (3.1) gives:

$$\frac{dW_1\left(C_s\right)}{dQ_s}=-Y_w\left[1-G_1\left(Q_s\right)\right]+C_sG_1\left(Q_s\right)+Y_s$$

When (3.2) =o, the optimal purchase quantity $Q_s^*=\frac{\alpha(C_s+Y_s)+\beta(Y_w-Y_s)}{C_s+Y_w}$ is obtained.

3.2. Supplier's Optimal Ordering Decision. Construct the ordering strategy of the raw materials platform based on the block database. The relationship between inventory costs and suppliers is as follows:

$$W_2\left(C_n\right)=Y_s\int_{Q_n}^{\infty}\left(Q_s-Q_n\right)g_2\left(Q_n\right)dQ_n+C_n\int_0^{Q_n}\left(Q_n-Q_s\right)g_2\left(Q_n\right)dQ_n+Y_nQ_n(3\cdot 3)$$

Taking the derivative of Q_n in (3.3) yields:

$$\frac{dW_2\left(C_n\right)}{dQ_n}=-Y_s\left[1-G_2\left(Q_n\right)\right]+C_nG_2\left(Q_n\right)+Y_n$$

If (3.4) is 0 , the manufacturer's optimal order quantity $Q_n^*=\frac{\alpha(C_n+Y_n)+\beta(Y_s+Y_n)}{C_n+Y_s}$ is obtained. 3.3 Manufacturer's Optimal Output Decision. Manufacturers can schedule production through vendor ordering decisions based on the block database. From the above assumptions, the formula for calculating the manufacturer's inventory cost can be obtained:

$$W_3\left(C_m\right)=Y_n\int_{Q_m}^{\infty}\left(Q_n-Q_m\right)g_3\left(Q_m\right)dQ_m+C_m\int_0^{Q_m}\left(Q_m-Q_n\right)g_3\left(Q_m\right)dQ_m+Y_mQ_m$$

Taking the derivative of Q_m in (3.5) yields:

$$\frac{dW_3\left(C_m\right)}{dQ_m}=-Y_n\left[1-G_3\left(Q_m\right)\right]+C_mG_3\left(Q_m\right)+Y_m$$

If formula (3.6) = o, the optimal product yield $Q_m^*=\frac{\alpha(C_m+Y_m)+\beta(Y_n+Y_m)}{C_m+Y_n}$ of the manufacturer can be obtained.

3.3. Model construction based on independent priority. Block database provides a good platform for information sharing. It enables the enterprises in each link of the supply chain of power materials to quickly obtain reliable information from the supply chain and downstream enterprises [16]. This paper develops a dynamic model based on independent dominance (Figure 3.1 cited in Processes 2021, 9(6), 982).

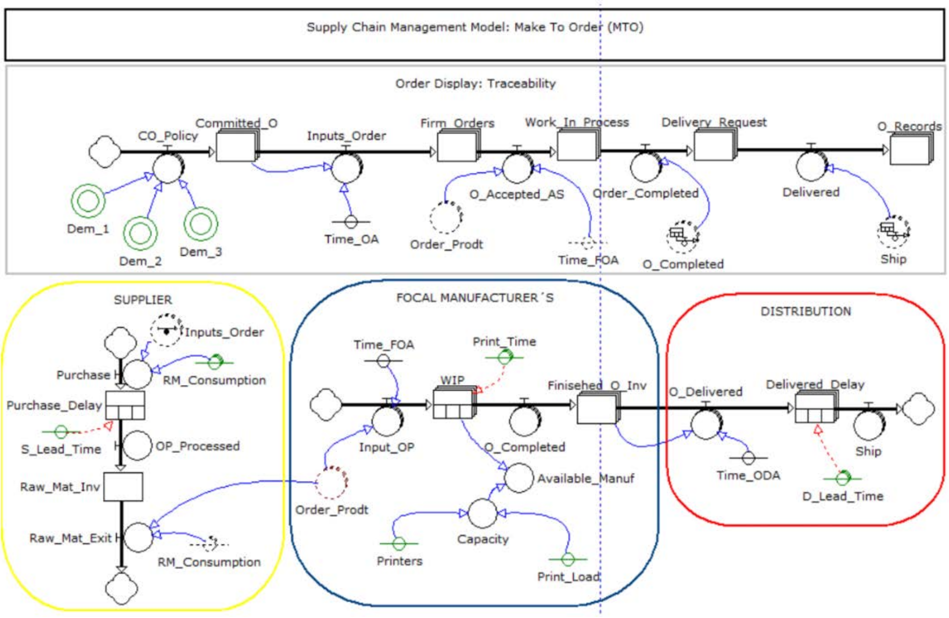

Fig. 3.1: System dynamics model under respective dominant modes.

3.4. Optimal Decision under Smart Contract Association. This project intends to introduce the power material management supply chain model based on blockchain technology to form a close cooperation relationship between producers, suppliers and raw material platforms through the raw material platform to share inventory. In contrast, suppliers share the cost of inventory [17]. Through the block database, the production planning of the supply chain is discussed, so $q_m = Q_m = Q_n = Q_s, C_c = C_s$. When the ordering decisions of these three people are the same, the inventory cost of the entire supply chain can be expressed by the following formula.

$$dW_4\left(C_c\right) = Y_w \int_{q_m}^{\infty} \left(K - q_m\right) g_1(K) dK + C_s \int_0^{q_m} \left(q_m - K\right) g_1(K) dK + Y_n q_m$$

Taking the derivative of q_m in formula (3.7) gives:

$$\frac{dW_4\left(C_c\right)}{dq_m} = -Y_w\left[1 - G_1(K)\right] + C_s G_1(K) + Y_n$$

When equation (3.8) = 0, the optimal production product $q_m^* = \frac{\alpha(C_s+Y_n)+\beta(Y_w+Y_n)}{C_s+Y_w}$ can be obtained.

4. Test and analysis. The black box test method is used to test it to check the performance and quality of the ubiquitous IoT power management system developed in this paper. The black box method tests the system software's function by inputting test cases and checking whether the output meets the expectations [18]. The functional test results of the intelligent management system for electric power materials are shown in Table 4.1. The performance test results of the intelligent management system for electric power materials are shown in Table 4.2. The test results of the database security of the intelligent management system for electric power materials are shown in Table 4.3.

5. Conclusion. This paper designs the physical and functional architecture of the intelligent management system of power materials based on the ubiquitous Internet of Things. Finally, an example is given to verify the performance indicators of the intelligent electric power logistics management system under the "ubiquitous Internet of Things" proposed in this paper, which meets users' requirements. The platform has a comprehensive

Table 4.1: System function test results.

Serial number	Test content	Output result	Test result
1	Label management	Consistent with the desired output	Successful test
2	Material management	Consistent with the desired output	Successful test
3	Inventory control	Consistent with the desired output	Successful test
4	Waste disposal	Consistent with the desired output	Successful test
5	System Administration	Consistent with the desired output	Successful test
6	Grass-roots administration	Consistent with the desired output	Successful test

Table 4.2: System performance test results.

Serial number	Test content	Test result
1	Parallel operand	P 1000
2	Data collection rate	95% or higher
3	LAN response time	<100 ms
4	User registration response time	3.6 s or less
5	Main menu response time	3.1 s or less
6	Timeliness of intelligence response	93% or higher
7	Static information integrity	93% or higher
8	Accuracy of information	93% or higher
9	Stability of system	No problems, such as system crash, occurred
10	Database stability	stable

Table 4.3: Results of database security tests.

Serial number	Exam question	Test result
1	Database security	The database is encrypted
2	Database integration degree	Complete database for all business activities to provide data support
3	Database data manageability	It supports the operation of adding, modifying and deleting system data.
4	Database independence	Independence from other systems
5	Database storage and recovery functions	In the event of an error, the database has a complete backup and can be restored quickly

function and a good security guarantee ability, and it can be well adapted to current power material management needs.

6. Acknowledgement. This article is the research result of the 2023 State Grid Shanxi Electric Power Company's technology project "Research on the Self evaluation Method of Sporadic Materials Based on Artificial Intelligence" (Project code: 52051W230001).

REFERENCES

[1] Oladele, T. O., Ogundokun, R. O., Adegun, A. A., Adeniyi, E. A., & Ajanaku, A. T. (2021). Development of an inventory management system using association rule. Indonesian Journal of Electrical Engineering and Computer Science, 21(3), 1868-1876.

[2] Balkhi, B., Alshahrani, A., & Khan, A. (2022). Just-in-time approach in healthcare inventory management: Does it really work. Saudi Pharmaceutical Journal, 30(12), 1830-1835.
[3] Pasaribu, J. S. (2021). Development of a Web Based Inventory Information System. International Journal of Engineering, Science and Information Technology, 1(2), 24-31.
[4] Bader, D., Innab, N., Atoum, I., & Alathamneh, F. (2023). The influence of the Internet of things on pharmaceutical inventory management. International Journal of Data and Network Science, 7(1), 381-390.
[5] 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.
[6] Agboola, F. F., Malgwi, Y. M., Mahmud, M. A., & Oguntoye, J. P. (2022). Development of a Web-Based Platform for Automating an Inventory Management of a Small and Medium Enterprise. FUDMA Journal of Sciences, 6(5), 57-65.
[7] Aris, M. A. M., & Salikon, M. Z. M. (2022). Development of Warehouse Inventory Management System: Pembangunan Sistem Pengurusan Inventori Gudang. Applied Information Technology and Computer Science, 3(1), 529-540.
[8] Thakre, S. (2021). study of the impact of jit (just–in time) in inventory management in the automobile sector India in. IJM, 12(2), 720-730.
[9] Yankah, R., Osei, F., Owusu-Mensah, S., & Agyapong, P. J. (2022). Inventory management and the performance of listed manufacturing firms in Ghana. Open Journal of Business and Management, 10(5), 2650-2667.
[10] Neve, B. V., & Schmidt, C. P. (2022). Point-of-use hospital inventory management with inaccurate usage capture. Health Care Management Science, 25(1), 126-145.
[11] Mahajan, P. S., Raut, R. D., Kumar, P. R., & Singh, V. (2024). Inventory management and TQM practices for better firm performance: a systematic and bibliometric review. The TQM Journal, 36(2), 405-430.
[12] Herlambang, C. A., & Parung, J. (2021). Information system design and inventory management on pharmacy business within ABC-XYZ analysis method. Airlangga Journal of Innovation Management, 2(2), 194-205.
[13] Kihara, B. W., & Ngugi, P. K. (2021). Inventory management systems and performance of public hospitals in Kenya; case of counties under universal Health care programme. International Journal of Social Sciences and Information Technology, 7(2), 66-77.
[14] Preil, D., & Krapp, M. (2022). Artificial intelligence-based inventory management: a Monte Carlo tree search approach. Annals of Operations Research, 308(1), 415-439.
[15] Ali, K., Showkat, N., & Chisti, K. A. (2022). Impact of inventory management on operating profits: Evidence from India. Journal of Economics, Management and Trade, 28(9), 22-26.
[16] Qi, M., Shi, Y., Qi, Y., Ma, C., Yuan, R., Wu, D., & Shen, Z. J. (2023). A practical end-to-end inventory management model with deep learning. Management Science, 69(2), 759-773.
[17] Dey, B. K., & Seok, H. (2024). Intelligent inventory management with autonomation and service strategy. Journal of Intelligent Manufacturing, 35(1), 307-330.
[18] Cahyono, A., & Titisari, M. A. (2023). Implementation of Erp-based Automated Inventory Management System at Sabana Fried Chicken Franchise Company. Journal of Economics and Business UBS, 12(5), 3307-3319.

Edited by: Hailong Li
Special issue on: Deep Learning in Healthcare
Received: Mar 18, 2024
Accepted: May 8, 2024