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ORIGINAL

STRATEGIC DISTRIBUTION AND SUPPLY CHAIN OPTIMIZATION FOR ATHLETIC PHARMACEUTICAL SUPPLIES: ENHANCING PERFORMANCE THROUGH INFORMATION-BASED MANAGEMENT

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ABSTRACT

Objective: This study aims to optimize the pharmaceutical supply chain management for athletic health care facilities through the application of an SPD (Supply, Processing, and Distribution) logistics model, enhancing both efficiency and cost-effectiveness. **Methods:** Utilizing a comprehensive SPD model, this research explores the refinement management of pharmaceutical supplies within athletic health care facilities. The study involved the implementation of an integrated information management system that connects the internal operations of sports medicine facilities with external pharmaceutical supply chains. **Results:** The introduction of the SPD logistics model facilitated a seamless connection between the internal structure of athletic health care facilities and the external supply chain, utilizing advanced supplier and product qualification systems. This integration not only streamlined in-hospital logistics operations but also significantly reduced circulation costs and improved data visualization across the entire supply chain. Quality evaluation systems for service items were developed, and the overall management of pharmaceutical supplies was optimized to support the specialized needs of athletes and sports medicine programs. **Conclusion:** The SPD logistics model provides a robust framework for the effective management of pharmaceutical supplies in sports medicine, offering significant improvements in operational efficiency, cost reduction, and quality of care. The model aligns with contemporary medical

reform policies aimed at enhancing the quality and efficiency of health care provision in the athletic sector, benefiting patients, suppliers, and health care facilities alike.

KEYWORDS: SPD Logistics; Supply Chain Model; Whole Process Informationization; Drug Supplies Management

1. INTRODUCTION

The management of pharmaceutical supplies within athletic health care facilities is crucial not only for the maintenance of day-to-day operations but also for ensuring the highest standards of athlete care and treatment efficiency. The evolution of supply chain management has introduced sophisticated models designed to streamline processes, reduce costs, and enhance service delivery, which is particularly relevant in the context of sports medicine where the timely and efficient provision of medical supplies can directly impact athlete recovery and performance. Supply, Processing, and Distribution (SPD) logistics is a model that has been increasingly adopted in various health care settings to improve the management of medical and pharmaceutical supplies. Originating from more general health care practices, the SPD model integrates advanced logistic and supply chain management techniques to create a seamless flow of supplies from procurement to clinical application. This model not only focuses on enhancing operational efficiency but also emphasizes cost-effectiveness and quality of care, aligning with the broader goals of medical reform and patient-centered care. In sports medicine, the unique demands placed on pharmaceutical supplies—from routine vitamins and supplements to critical injury-related medications—require a robust management system that can handle a dynamic and sometimes unpredictable demand. The implementation of SPD in this context offers a promising solution by ensuring that medical supplies are efficiently managed, properly distributed, and available when needed, which is essential for the treatment and prevention of injuries in athletes (Zhang et al., 2022). This introduction of SPD into athletic health care settings also addresses several challenges, including the management of low-value drugs and consumables that are frequently used in sports-related treatments. The high costs associated with these supplies can place significant financial pressure on health care facilities and patients alike. By optimizing the supply chain and reducing unnecessary expenditures, the SPD model can help in managing these costs more effectively. Moreover, the integration of comprehensive information management systems within the SPD framework enhances transparency and accountability in the supply chain. It allows for the precise tracking of pharmaceuticals from procurement to usage, ensuring that all stakeholders—health care providers, athletes, and regulatory bodies—have access to accurate and timely information (Ma et al., 2022). This level of data visibility is crucial for maintaining compliance with health standards and for facilitating continuous improvement in supply chain processes. Thus, the

application of the SPD logistics model in the context of sports medicine not only improves the management of pharmaceutical supplies but also significantly contributes to the overall efficiency, effectiveness, and quality of athlete care. This paper aims to explore the implementation and outcomes of the SPD model within athletic health care facilities, highlighting its impact on operational efficiencies, cost management, and the quality of medical care provided to athletes. A part of the hospital development trend fast, has long been implemented more mature medical machinery logistics management, can be meticulously planned before accounting for costs, in order to be able to communicate timely logistics management, so that it achieves satisfactory actual results, but also in the exploration of building SPD system software, to create a regional medical machinery logistics distribution center, to achieve intelligent, systematic management (Elanor, 2023).

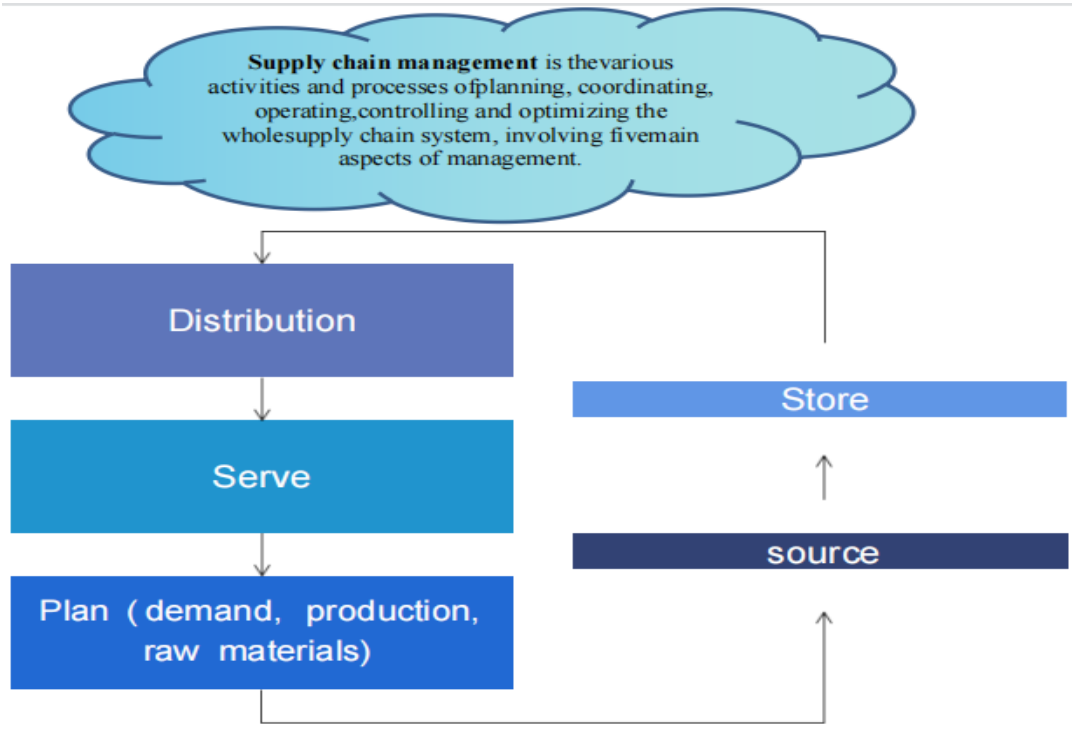

Figure 1: Supply Chain Management Model

2. Method

2.1 Theory related to SPD supply chain management

2.1.1 SPD supply chain related concepts

SPD is a set of medical consumables logistics supply system including supply, processing and dispatching by the standardized construction of information system and reshaping of logistics in the hospital and its barcode identification technology. The system is constructed to complete the seamless connection of supply data information among patients, clinical departments,

medical equipment units, logistics distributors, suppliers and manufacturers (Chu, 2021). Table 1 shows the comparison table between SPD operation mode and traditional mode.

Table 1: Comparison table of SPD business model and traditional model

TRADITIONAL MODEL BUSINESS STEPS	SPD MODEL BUSINESS STEPS	TIME SAVING OF SPD MODE COMPARED TO TRADITIONAL MODE
MANUAL INVENTORY OF CURRENT STOCK LEVELS	System displays current inventory levels	9
MANUAL FILLING OF DEMAND PLAN	The system automatically pushes the replenishment plan	8
MEDICAL EQUIPMENT DEPARTMENT STOCK CLERK REVIEW	Operating room stock clerk review	1.5
MEDICAL EQUIPMENT DEPARTMENT PURCHASER REVIEW, TELEPHONE ORDER	Medical equipment department purchaser review, telephone order	13
DELIVERY AND ACCEPTANCE	Delivery and acceptance (scanning code acceptance)	18
MANUAL STOCKING	Manual stocking (scanning code stocking)	8
TOTAL		57.5

2.1.2 Construction of logistics information SPD system

SPD system is open to the outside and interfaced with the logistics information management (enterprise resource planning, ERP) system of upstream suppliers according to the cloud platform, and internally with the hospital information system (hospital information system, HIS), surgical anesthesia system and internal structure risk control system. SPD system is open to the logistics information management (enterprise resource planning, ERP) system of upstream suppliers according to the cloud platform, and internally interfaced with the hospital information system (hospital information system, HIS), surgical anesthesia system and internal structure risk control system. Internal interfacing with hospital information system (Hospital Information System, HIS), surgical anesthesia system and internal structure risk prevention and control system constitutes an information system covering the whole process of internal and external logistics, in-hospital logistics and internal control audit. The information flow advertising entity model of medical consumables supply chain platform is shown in Figure 2. According to the supply chain service way of SPD according to the regional cloud platform order information, truck distribution data processing, engineering subcontracting code, in-hospital and out-of-hospital depot, in-hospital depot, logistics distribution service, etc., connect upstream and downstream suppliers, dispatch service providers, clinical departments, and complete the transformation of medical consumables from guaranteed supply logistics to

consumption application logistics (Deng et al., 2020).

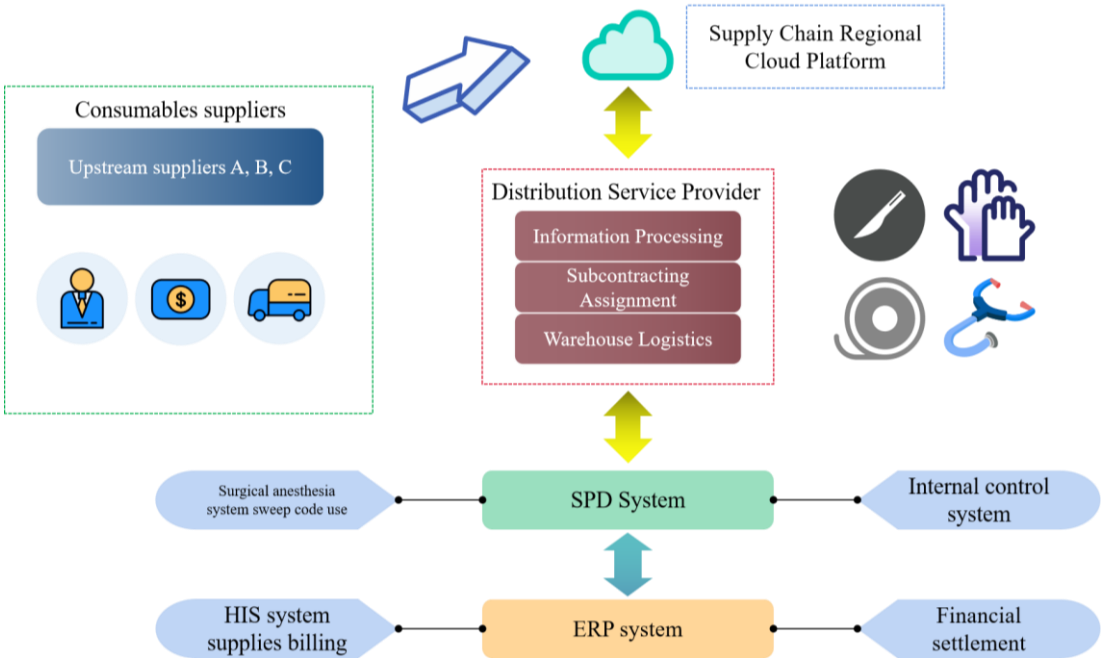

Figure 2: Information flow model of medical consumables supply chain platform

2.2 Common methods of supply chain management

There are three common approaches to supply chain management as follows: distributed, integrated and collaborative, which are the three historical stages of supply chain management development so far (Tang et al., 2020).

2.2.1 Distributed Management

In the early stage of enterprise development, enterprises generally only focus on cost control to maximize personal interests, and rarely consider the interests of upstream, midstream and downstream enterprises, and make decisions based on personal interests alone, which is difficult to ensure the overall benefit of the whole supply chain. In the process of supply chain management, enterprises at each connection point should have the overall goal of common rights and interests, and should analyze and consider the problems from the overall interests, so as to achieve the best overall interests, and the communication and sharing of information among the upstream, midstream and downstream enterprises must be greatly strengthened, so that this special cooperation relationship can not only improve the overall operation efficiency of the supply chain, but also reduce the business risks and reduce the cost of the supply chain. The cost of the supply chain, a triple benefit (Tang, 2023).

2.2.2 Integrated Management

Such a management model is usually used in monopolistic or

oligopolistic markets, because only in such competitive situations can the leading company connect every link in the entire supply chain. In order to maximize the overall benefits and further extend the overall advantages of the supply chain, the integrated management approach comes to the fore because it can respond quickly to the management decisions of the supply chain. However, in the actual environment, there are fewer and fewer leading companies with similar advantages, and it is difficult for a large number of companies with the same objectives to form integrated operations among themselves to maximize their own interests.

2.2.3 Collaborative Management

According to the continuous development and update of information technology, the communication and coordination of each node in the supply chain is becoming more and more convenient, which can effectively improve the overall operational efficiency of the supply chain and the supply chain performance assessment, however, this requires that each connecting enterprise in the supply chain has relatively high information sharing ability, and each enterprise can adjust the production planning and operation plan according to this shared information, and harmonize the production operation, so as to achieve the overall cost reduction, efficiency improvement, and operational collaboration of the supply chain group members (Li et al., 2021).

2.3 Pharmaceutical and consumables supply chain management

2.3.1 Medicine and consumables distribution situation

By distribution, we mean the whole process of products from manufacturing to wholesale price to retail terminals. Thus, the circulation of drugs mainly includes the whole process of production by pharmaceutical enterprises, distribution by wholesale enterprises or distributors, and finally retailing by retail terminals such as hospital outpatient clinics and pharmacies. As we all know, before the 1980s, China was still in the era of planned economy, and drugs were part of the planned economic system, the core of which followed the three-tier wholesale price system to carry out the circulation, which was expressed as "unified purchase and sale, and gradual transfer".

In this way, the traditional form of pharmaceutical distribution enterprises to achieve profits are mainly concentrated in the process of drug wholesale and distributors, according to the sale price difference to achieve increased efficiency. This wholesale distribution system has many steps and stages, and even in a typical regional center, patients need to go through 2-3 stages to get the drugs they need, while most remote areas need to go through up to 6 complex steps. Figure 3 shows the whole process of traditional Chinese medicine distribution.

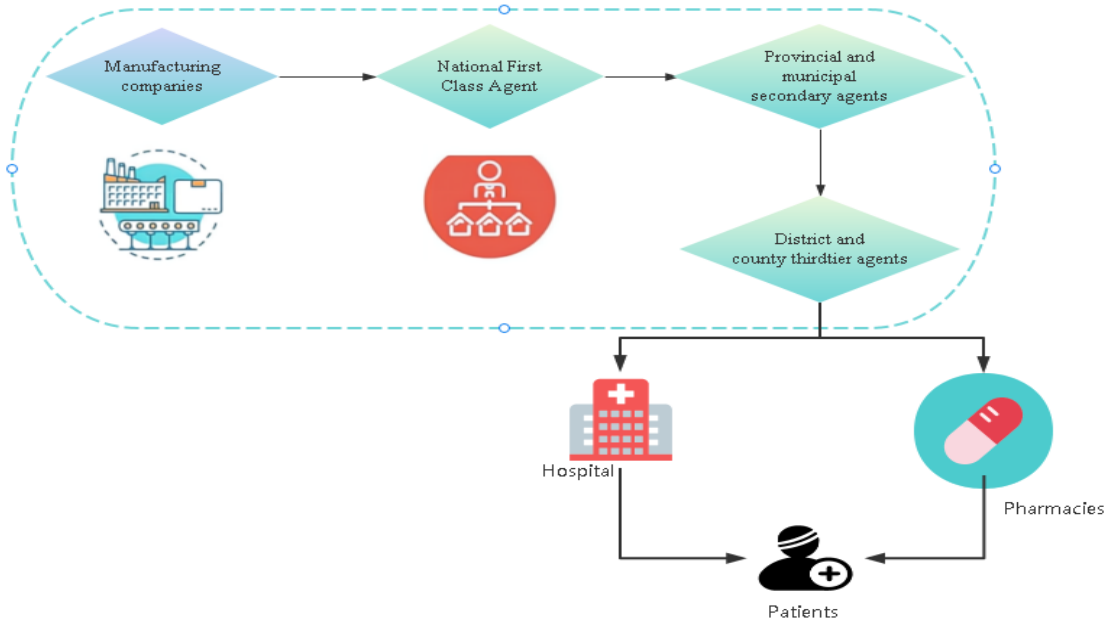

Figure 3: China's traditional drug distribution process

In terms of the current pharmaceutical supply chain, most of them include upstream and downstream raw material suppliers, manufacturing enterprises, midstream and upstream pharmaceutical distribution distributor enterprises, midstream and downstream designated medical institutions, retail pharmacies, private clinics and other retail terminals. As a key node in the pharmaceutical supply chain, the pharmaceutical distribution distributor plays a leading role in the production and dispatching function, which is of great significance to the stability and development trend of the whole pharmaceutical supply chain. At this stage, our country's pharmaceutical distribution enterprises are in the key stage of transformation and development. In the near future, pharmaceutical distribution enterprises in China will target more development trends in the pharmaceutical industry related to product or service value-added level, taking into account cost reduction and efficiency improvement (Tsai, 2021).

2.3.2 Pharmaceutical supply chain model

Figure 4 shows the pharmaceutical supply chain entity model. However, the concept of pharmaceutical supply chain management has not been clearly defined yet, and it is usually believed that the meaning of pharmaceutical supply chain management is to improve the quality of treatment services, improve the quality of drug distribution and enhance the overall operational efficiency. According to the collaborative efforts of enterprises at each connection point in the supply chain management drive chain, many network resources in the supply chain management are efficiently planned, coordinated and managed and manipulated in a unified manner, so as to become an integrated institution through the whole process of cash flow, logistics and information flow advertisement to complete the smooth acquisition, manufacturing, warehousing

and dispatching in the whole circulation chain (Tsai, 2021; Yao, 2020).

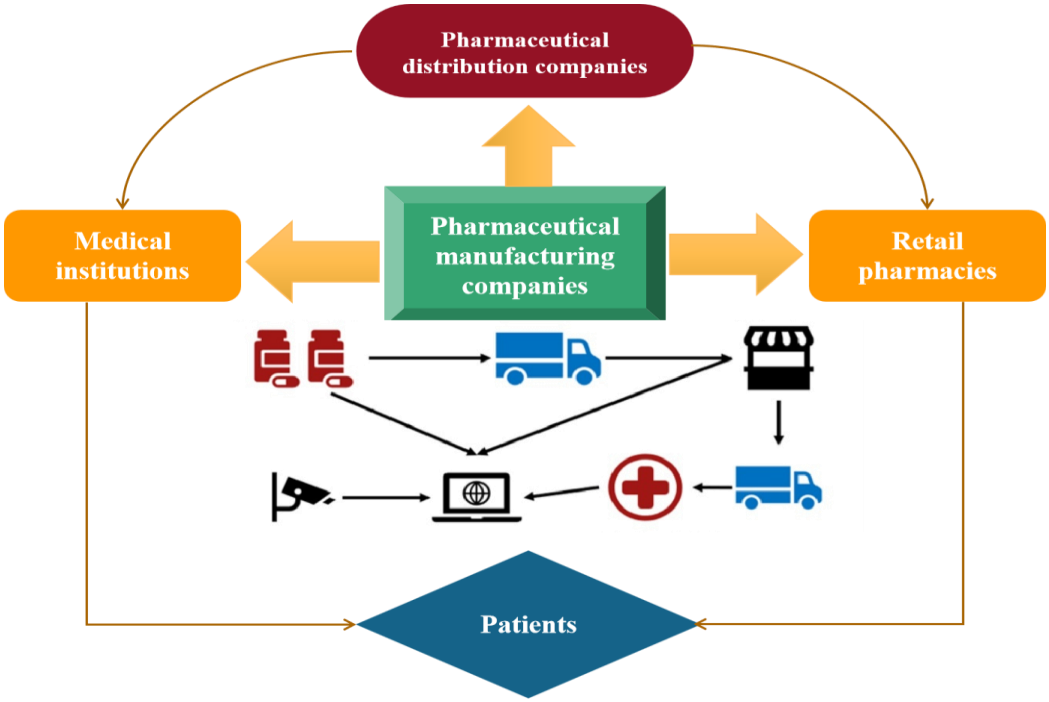

Figure 4: Pharmaceutical supply chain model

After the introduction of SPD system drug supervision, through the platform's complete basic parameters and the integration of accurate inventory management, the pharmacy understands the contents of the pharmacy's consumption information, and the drug supply chain becomes more and more transparent and simple, and the drug supply method changes from the traditional "pull" method of "pharmacy receiving → pharmacy arranging delivery" to the "push" method of "pharmacy mastering pharmacy consumption → pharmacy actively filling". The drug supply method has changed from the traditional "pull" method of "pharmacy pickup → pharmacy delivery" to the "push" method of "pharmacy control of pharmacy consumption → pharmacy active filling". This is also an important innovation in the supply of outpatient drugs in hospitals (Kramarz & Kmiecik, 2022).

2.3.3 Example of SPD platform establishment

(1) Network environment Firewall; 10M fiber.

(2) Data server establishment: hpdl388gen8, e5-2620v2, 32g memory, RAID 1 for disk 1 and 2, raid 5 for disk 3-7, and hot standby for disk 8. The database service was designed and installed with the Windows Server 2008r2 operating system, and Oracle11g was used for the database.

(3) system development and software operating environment software and system operating environment: Windows operating system, nc57

framework; development tools: Eclipse + Oracle10g; development language: Java.

(4) Development instructions: The software is developed based on the nc57 framework, and the application is written in java language. The software is written in strict accordance with the requirements of nc57 development specification, and the data operation layer, data display management layer and business logic management layer are strictly separated, so as to design a set of applications with high reusability and easy system maintenance.

(5) Important modules of SPD platform: The important modules in the supply chain platform include logistics product management, settlement, inventory management, invoice management and other modules to centralize the information of logistics goods statistics.

2.4 Implementation process of SPD pharmaceutical supply chain project

SPD pharmaceutical supply chain management mechanism, to put it plainly: S stands for Supply, P stands for Processing, and D stands for Distribution, which also corresponds to the three core tasks of material operation in the hospital. In fact, the hospital is a professional provider of medical strength, but it is not a professional organization for material operation. Therefore, under the SPD pharmaceutical supply chain management mechanism, hospitals outsource the distribution of medical supplies to pharmaceutical distribution companies, which are more professional in the innovation of distribution management methods, and hospitals only indicate their requirements to pharmaceutical distribution companies, and distribution companies will do the follow-up work of acquisition, delivery, supply, storage and transportation, so that designated medical institutions and distribution companies can achieve mutual benefits and win-win situations. Each does its part, and professional things are handed over to professional teams, which significantly reduces the cost of drug distribution. At present, dozens of large and medium-sized public tertiary hospitals in China have started to implement SPD management mechanism (Li, 2022). SPD operation management platform is a multi-organizational structure and multi-system collaboration platform, involving hospital material distributors, hospital SPD material warehouses, and various hospital consumption departments, based on the overall framework of the service platform, mainly divided into three layers.

(1) In-hospital and out-of-hospital distributor cooperation service control module: undertake the supply chain cooperation service of out-of-hospital materials, mainly including: B2B collaborative office software, ERP intelligent management system.

(2) In-hospital SPD supply chain service control module: undertake the internal structure of the hospital material supply chain management method, in

order to realize the rational collaboration of the supply chain in the hospital and inside and outside the hospital, the key system is: hospital supply chain intelligent management system.

(3) Public service control module: The public service control module is the data and information service system bus of the hospital SPD supply chain management system, realizing the integrated service with the hospital intelligent management system (HIS), hospital HRP system software, and hospital intelligent terminal equipment jack service, and undertaking the integrated service with B2B inside and outside the hospital together, so that the systems inside and outside the hospital can maintain high efficiency. The SPD system architecture is shown in Figure 5.

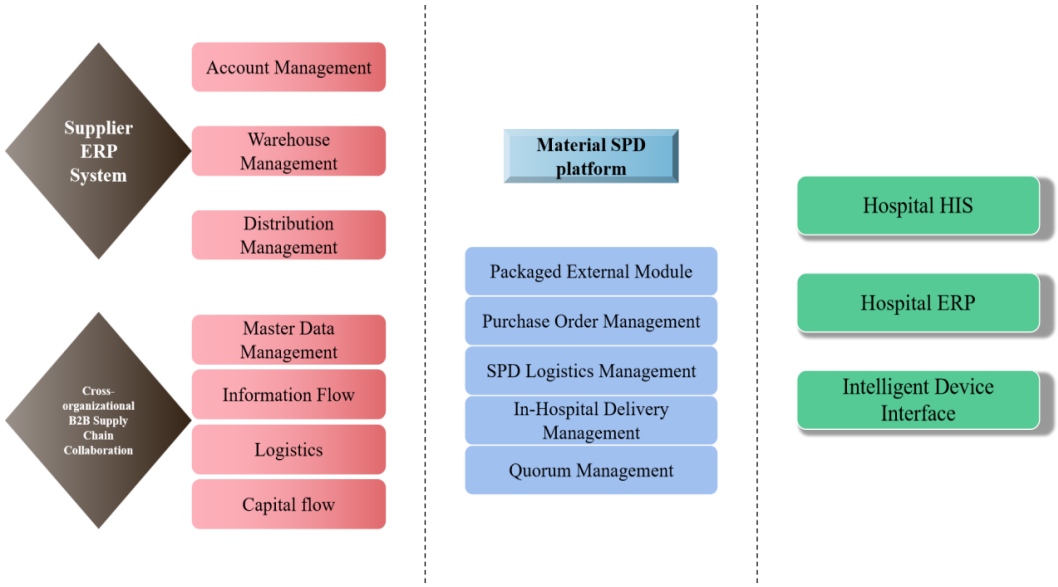

Figure 5: SPD system architecture diagram

3. Results and Discussion

3.1 SPD pharmaceutical supplies supply chain refinement management model

3.1.1 Introduction of SPD information system to interface with hospitals

Figure 6 shows the architecture of SPD information system. The functional modules of the supply chain platform include drug requisition and receipt management, drug settlement, invoice management, drug inventory management and report management. The supply chain platform system is connected to the HIS system of our hospital, and the daily drug consumption quantity is uploaded to both the HIS system and the supply chain platform system, and the drug consumption information in the supply chain platform system only involves the drug balance quantity but does not contain the specific information of prescriptions. All pharmacies and other secondary warehouses

are connected to the supply chain platform, so as to realize the function of automatically loading and unloading drugs after receiving them, and to manage drug batch numbers in the platform system (He, 2020; Li, 2022).

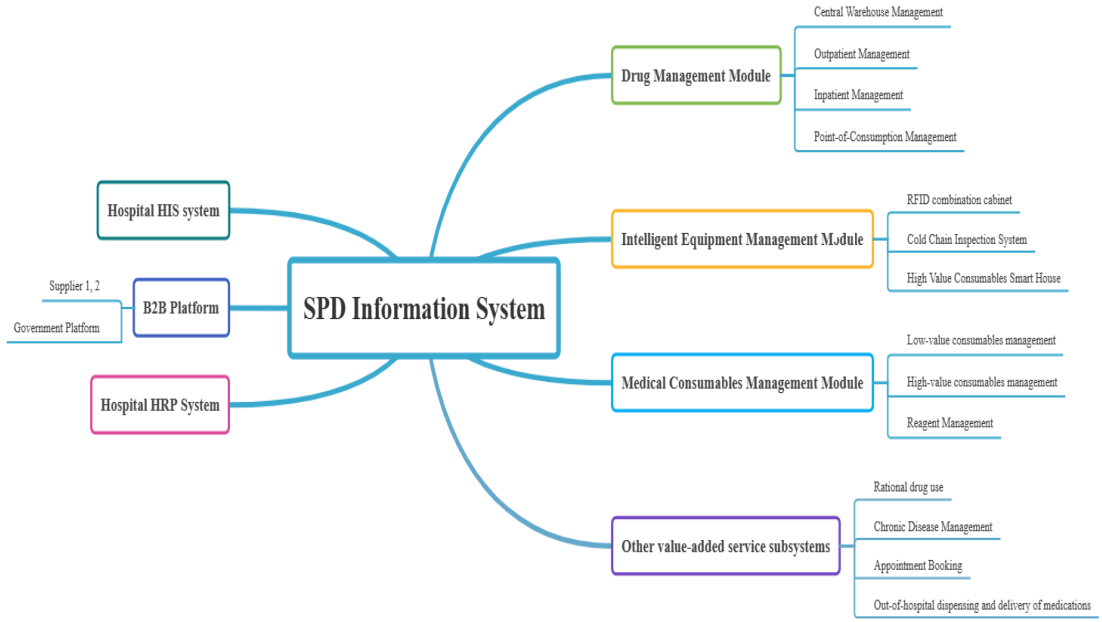

Figure 6: SPD Information System Framework

3.1.2 Drug distribution

For the handover of drugs from inpatient pharmacies to SPD logistics personnel, two-way drug handover cabinets are used. Pharmacists distribute drugs from inpatient pharmacies to each cabinet by ward, and logistics personnel open the doors of the cabinets from the outside in the designated area at regular intervals to load drugs from each ward into their respective transport boxes. This ensures the distribution and handover of drugs and keeps the pharmacy clean and orderly, and the SPD supply chain delivery is handled by special logistics personnel, with a dedicated area and locked cabinets. Specially designed drug transport boxes with locks are used, which are unlocked by nurses upon arrival at the ward and counted in person to ensure that the drugs are not contaminated by other people's private hands or touches during transport. When transporting all cold chain drugs, SPD transporters are required to use special cold chain boxes to ensure the quality of drugs. After the pharmacist of the emergency pharmacy dispenses the intravenous infusion drugs, they are directly delivered by the delivery trolley along the established track to the infusion room automatically and received by the emergency infusion nurses, avoiding the phenomenon of patients touching the infusion drugs and missing or damaging them (Tayyab et al., 2022).

3.1.3 Medication use

At the end of the SPD supply chain, the same advanced technology is

used for management, including the automatic dispensing machine used in the outpatient pharmacy and the automatic medicine wrapping machine used in the inpatient pharmacy. In outpatient clinics, automatic dispensers are used. Patients go to the numbering machine to get a number before taking medication, and the machine's intelligent system will divide the window and give the queue sequence number according to the type of medication needed by the patient. Dispensing is done by hospital pharmacists and medication instruction as required, while back-end dispensing and dispenser replenishment are handled by SPD supply chain pharmacy staff. Again, the SPD staff dispenses the medication, the hospital pharmacist double-checks, and the SPD supply chain transporters deliver the medication to each ward (Wang, 2022).

3.2 SPD pharmaceutical supply chain implementation steps

3.2.1 Drug scanning and warehousing

The drug entry operation in the traditional HIS system is manually operated by the pharmacist in the system, and the operation requires the entry of supplier, commodity information, quantity, batch number, expiration date, invoice date and other information. The manual entry is inefficient and error prone. After using the intelligent hospital drug management system, the system introduces the QR code scanning function. When the supplier makes a delivery, the QR code information corresponding to this delivery is printed at the same time. When the pharmacist operates the system, he or she can click Add in the inventory interface, select the QR code, and scan the QR code with the QR code data collector to automatically generate the drug inventory information, which eliminates manual entry, improves the efficiency of entry, and greatly reduces the chance of errors (Abbas et al., 2020).

3.2.2 Intelligent SPD based warehouse with fixed number management

Company has renewed the various warehouses of Hospital A and implemented a fixed number of management mechanisms. Transparency of the pharmaceutical supply chain, according to the configuration of a series of automated machinery, build intelligent system SPD warehouse that corresponds to the drug distribution system software, picking efficiency and accuracy are certain to ensure, immediately conducive to enhance the safety of drug taking coefficient (Haial et al., 2020). For the core drug warehouse, company updates the storage shelves, applies the rfid tag, completes the refinement cargo position management, the information content electronic work, from the beginning of the incoming warehouse, does the basic parameters of the fixed number and its secondary inventory value warning, must carry out research, setting and maintenance of the fixed number of each species; but for the incoming and outgoing pharmacies and other secondary warehouses, company funds to invest in automatic dispensing machine, automatic granule

stripping machine. However, for secondary warehouses such as in- and outpatient pharmacies, has invested in intelligent products such as automatic dispensers, automatic granulators, and automatic wrapping machines, and at the same time has made good index relationships, thus creating an instant connection between inventory and stocking details, replacing the original pickup scheme, and thus generating good news at the level of personnel and time consumption. In this way, in the pharmaceutical logistics supply chain as a whole, the original passive mode of "picking up and arranging delivery" has been transformed into an active mode of instantly transmitting stocking regulations.

3.2.3 Formation of a hospital-based team for SPD pharmaceutical supply chain projects

In order to ensure the practical effectiveness and efficiency of the daily operation of the SPD supply chain, the third party will continue to establish a new SPD pharmaceutical supply chain project resident elite team. This team is responsible for the whole process of supply chain of hospital medical supplies, which can alleviate the pressure of operating costs of hospitals for drug operation from a more efficient perspective. The structure of company's new SPD pharmaceutical supply chain team at the hospital is shown in Figure 7.

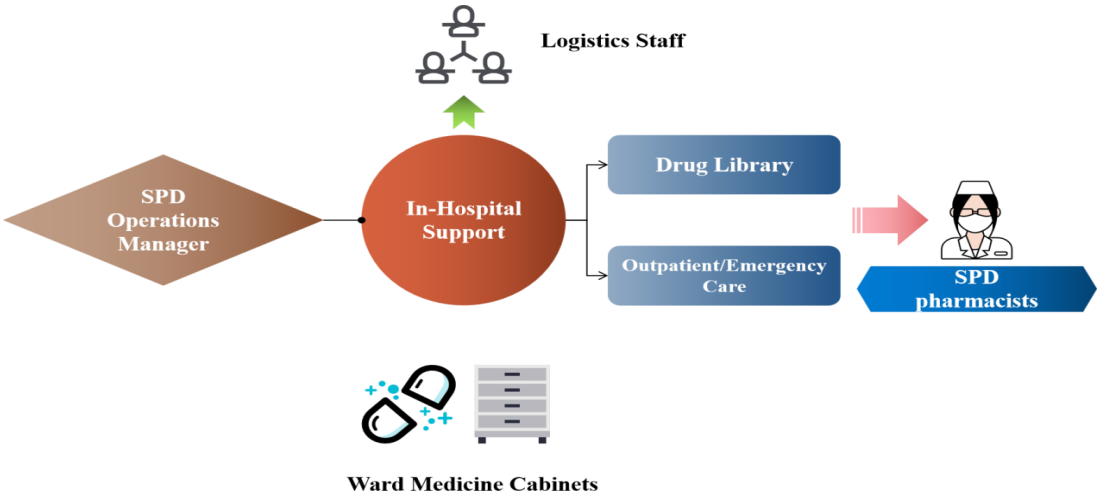

Figure 7: Organizational chart of SPD project team

3.3 Comparative analysis of the cost of inventory behavior under the traditional model and the new model of SPD

3.3.1 Analysis of the inventory strategy and its cost structure in the traditional model

Using the Internet, Internet of Things, RFID and other information technology, locking the whole process from upstream suppliers to the final patient use, covering multiple hospital areas, all wards, and with the hospital's

HIS, LIS and other software to achieve "interoperability", the implementation of SPD information system as the core, supplemented by PDA, scan gun, bar code, by The hospital prepared section management, the hospital SPD center library to implement the operation of the diversified multi-dimensional service management model. The management mode can realize the hospital medical materials procurement management, order management, distribution management, out-of-hospital supplier management, in-hospital SPD central library management (including code assignment, acceptance, shelves, picking, processing, out of the warehouse, review, etc.), all levels of consumption point of management (including shelves, sweep code consumption, etc.), bill management and basic information management. In fact, in the traditional mode, the hospital as the demand side usually uses the EOQ method to interpret and calculate the best order quantity Q, while the third party takes the integer multiple of the best order quantity Q provided by the demand side as its own order quantity (to facilitate the creation of the formula later, this integer multiple is set to m) (Wang & Jie, 2020). The graphical representation of the stock quantity behavior of hospitals and pharmaceutical distribution companies' enterprises in the traditional model is shown in Figure 8 below.

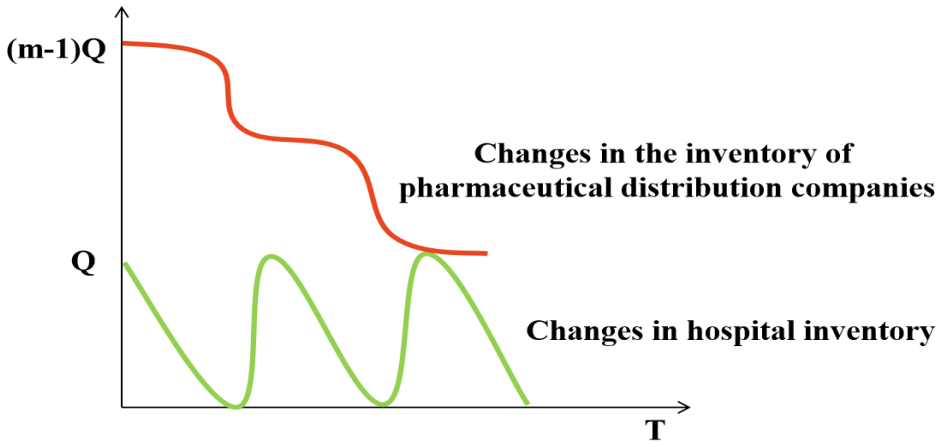

Figure 8: Inventory changes in hospitals and pharmaceutical consumables distribution companies under the traditional model

Therefore, when implementing the traditional supply chain management model, the cost structure of the hospital as the demand side can be expressed as:

$$C_D = \frac{s_D D}{Q_D} + \frac{h_D Q_D}{2} \quad (1)$$

Meanwhile, the cost structure on the part of the pharmaceutical distribution company can be expressed as follows:

$$C_S = \frac{s_D D}{Q_D} + \frac{s_S D}{m Q_D} + \frac{(m-1) h_s Q_D}{2} \quad (2)$$

Where D represents the demand from the hospital, QD represents the order quantity of the hospital; CD represents the inventory stock cost of the hospital as the demand side, and the optimal order quantity is determined according to the EOQ model, and the inequality group used to determine the optimal m is as follows.

$$\begin{cases} C_S^R(\text{Optimal m, Q}) \le C_S^R(\text{Optimal m} + 1, \text{Q}) \\ C_S^R(\text{Optimal m, Q}) \le C_S^R(\text{Optimal m} - 1, \text{Q}) \end{cases} \quad (3)$$

And if a further restrictive constraint W is added, using W as the maximum inventory g capacity of the pharmaceutical distribution company, the equation used by company to determine the optimal m can be derived as:

$$\begin{cases} \text{Optimal m} \cdot Q \le W \\ (\text{Optimal m} + 1) \cdot Q_D \ge W \end{cases} \quad (4)$$

3.3.2 Analysis of the inventory strategy and its cost structure after the introduction of SPD

With the introduction of the SPD strategy, the work and authority of ordering and inventory shifted more from the hospital as the demand side to the SPD company segment of the pharmaceutical distribution company, and therefore its inventory cost structure changed significantly. Where the cost composition of suppliers became.

$$C_S^{VMI} = \frac{(S_D+S_P)D}{Q_D} + \frac{S_S D}{mQ_D} + \frac{[h_D(m-1)h_S]Q_D}{2} \quad (5)$$

Thus, the choice of the optimal solution for the pharmaceutical distribution company SPD is further explored, and when the SPD company obtains the optimal solution, it means that it minimizes its inventory cost. It can be concluded that in order to obtain the minimized CS, QD and m form a certain interrelationship, which is expressed in the form of an equation as follows.

$$Q_D(m) = \sqrt{\frac{2m(S_D+S_P)+2S_S D}{2mh_D+m(m-1)h_S}} \quad (6)$$

Therefore, company, a pharmaceutical distribution company, determines its optimal minimum inventory cost based on the following equation.

$$Min - C_S^{VMI} = \frac{(S_D+S_P)D}{Q_D} + \frac{S_S D}{mQ_D} + \frac{[h_D(m-1)h_S]Q_D}{2} \quad (7)$$

And also satisfy the constraints as follows.

$$\begin{cases} m \in \text{Positive Integer} \\ G = mQ_D(m) \leq W \end{cases} \tag{8}$$

If G < W, the calculation continues with m = m + 1, until G ≥ W. At this point, the value of m and QD is found to be the optimal solution to satisfy the reality and to minimize the inventory cost of the pharmaceutical distribution company.

3.3.3 Construction of SPD pharmaceutical supply chain total cost optimization model under VMI strategy

The cost structure of Hospital A, representing the demand side, for medical supplies is expressed as:

$$T_D^V(n,q) = \frac{A_D d}{Q_D} + \frac{\pi_D Q_D}{2} = \frac{A_D d}{nq} + \frac{\pi_D nq}{2} \tag{9}$$

In the above equation, TD represents the total cost of medical supplies for Hospital A on behalf of the demand side, AD represents the order cost of the hospital, d represents the annual demand rate of Hospital A, QD is the order quantity (the order quantity will be divided into n shipments, and the quantity of each delivery is set to q, so QD =nq and n is an integer), πD represents the opportunity cost faced by Hospital A under the contract with the current supplier, i.e., the opportunity cost of missing out on other service providers or producers after forming a contract with company. The opportunity cost of the possibility of missing out on other partner service providers or producers after forming a contract with company. Correspondingly, the cost structure of pharmaceutical manufacturers and distribution companies company, representing the supply side, for pharmaceutical supplies is expressed as

$$T_S^V(m,q) = \frac{A_S d}{mq} + \frac{(h_S m + h_B)q}{2} - \frac{h_S mq}{2}\left[\frac{d}{p} + \frac{1}{m} - \frac{2d}{mp}\right] + \frac{Z_S d}{q} \tag{10}$$

In the above equation, TS denotes the total cost of the pharmaceutical manufacturer and the distribution company SPD, representing the supply side, for pharmaceutical supplies, AS denotes the production start-up cost, d still denotes the annual demand rate for hospital A, mq (QS) is the production volume used by the producer to schedule production by reference, hs is the holding cost per unit of inventory on the supply side, hD is the holding cost per unit of inventory on the demand side, p is the annual productivity of the producer , ZS is the delivery cost of delivering an order quantity of goods.

3.4 The implementation process of SPD pharmaceutical supply chain informationization project

SPD pharmaceutical supply chain model is divided into two types: SPD

automatic replenishment model and ticketed goods with industry model. Among them, the ticketed goods with industry mode is applicable to self-made Chinese medicine preparations, special drugs, raw materials, dangerous goods, and temporary medication, and all others adopt SPD automatic replenishment mode. The SPD pharmaceutical supply chain model is divided into four key parts: access approval, SPD replenishment, clinical medical use and consumption (Ahmad, 2022).

3.4.1 Access approval

The drug access approval process involves the participation of four entities: the Pharmacy Board, the Exchange, the pharmacist and the company. All medications that must be purchased by company providers for replenishment (including common and temporary unique medications) require approval by the hospital to generate a list of access documents before they can be purchased (Laganà & Colapinto, 2022; Papalexi et al., 2021). The access approval process is divided into two types of drug approval and emergency drug approval according to the drug application. In this paper, we use the common new drug approval as an example, as shown in Figure 9.

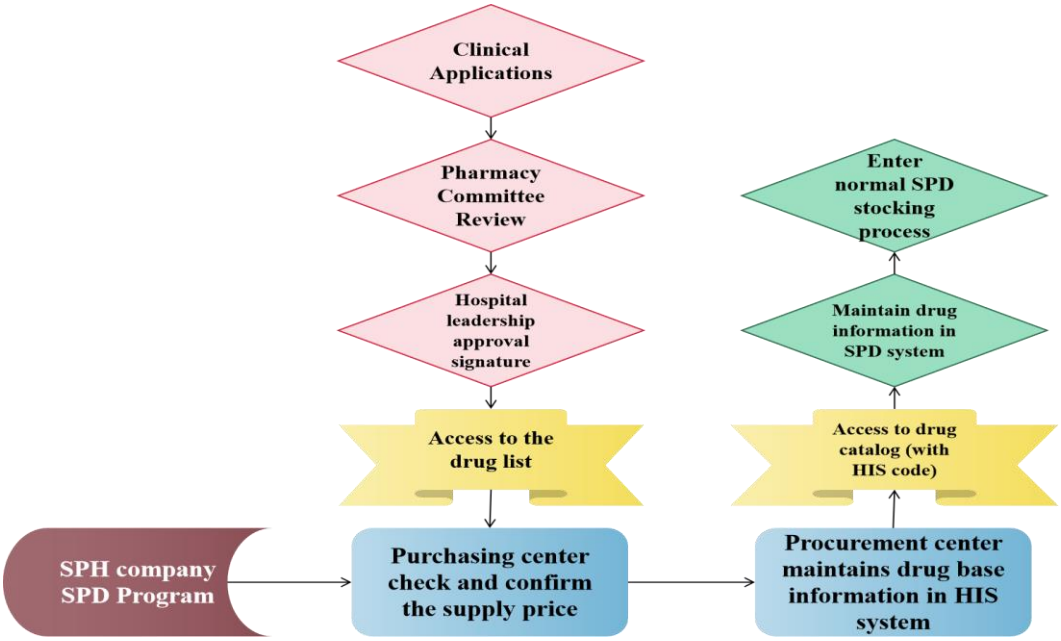

Figure 9: Flow chart of new drug approval

3.4.2 Stocking inventory

The intelligent drug distribution system can record the storage and usage of drugs in the ward in a timely manner and can check the expiration date information of drugs in real time. Combined with the intelligent medicine cabinet, the physical location of the medicine can be locked, and when the nurse needs to pick up the medicine, she can get the required medicine at the first time

according to the reminder of the medicine cabinet (Riaz et al., 2022). The intelligent distribution system of medication in the ward can effectively improve the level of medication management in the ward and ensure the safety of medication for patients. The SPD stocking process of drugs is divided into three methods according to the application of drugs: SPD fully automatic replenishment, ticketing and stocking in the same industry, and stocking in stock. In this paper, we take SPD fully automatic replenishment as an example, and the flow chart is detailed in Figure 10.

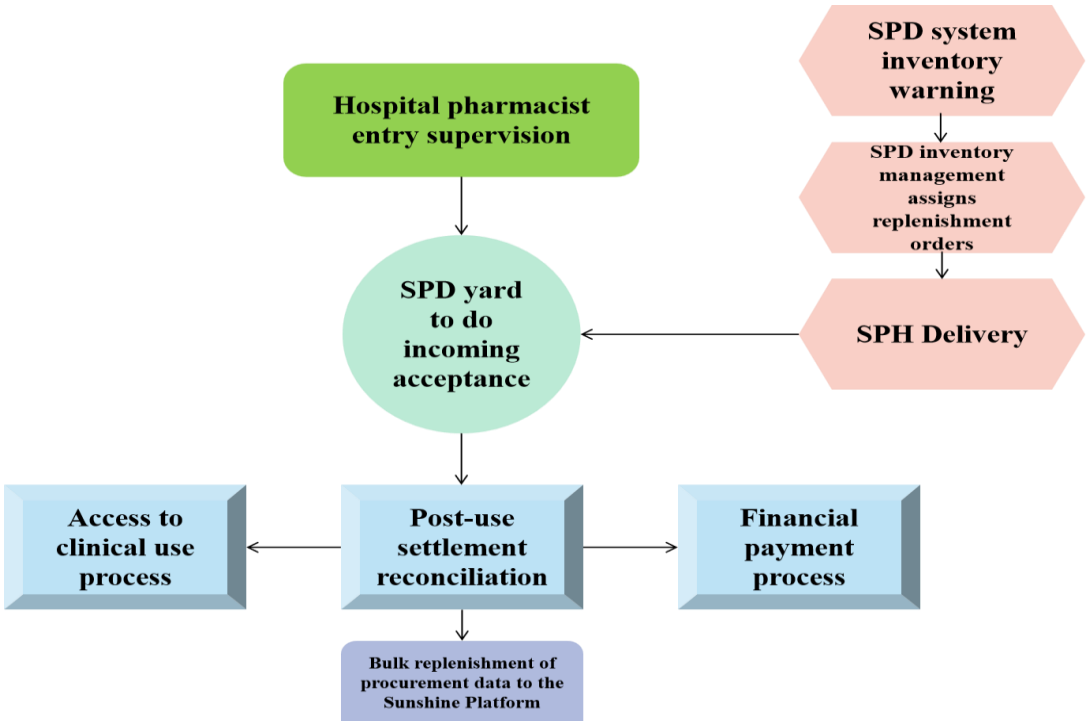

Figure 10: SPD automatic replenishment flow chart

(1) The SPD system software sends out warning information when the inventory is tight, and the SPD warehouse manager formulates the replenishment order based on the warning prompt, and the enterprise distributes it.

(2) Third-party warehouse management carries out incoming engineering acceptance based on the replenishment order, verifying the total number and production lot number, and hospital physicians carry out supervision. The drug then goes into the clinical medicine application process according to the clinical medicine requirements.

(3) Determine the consumption and then enter the use after clearing and checking process, here it is affirmed that the procurement data must be replenished to the sunshine procurement platform again in large quantities. The accounts are cleared on a monthly basis and confirmed to be correct to enter the accounting payment process.

4. Conclusion

The integration of the Supply, Processing, and Distribution (SPD) logistics model within sports medicine has demonstrated significant potential to enhance the management of pharmaceutical supplies, streamline operations, and improve the overall quality of athlete care. By adopting this model, athletic health care facilities can achieve greater operational efficiency, reduce costs, and ensure the timely availability of essential medical supplies critical for athlete treatment and recovery. This study has highlighted the benefits of implementing SPD logistics in managing the complex supply chains associated with sports medicine. The model not only facilitates better inventory management and cost control but also enhances the transparency and traceability of medical supplies, which is crucial in maintaining high standards of athlete care and regulatory compliance. Moreover, the shift towards a more integrated and information-driven supply chain management approach helps in minimizing waste, reducing errors, and improving the responsiveness of medical services to the dynamic needs of athletes.

Furthermore, the proactive management of pharmaceutical supplies through SPD can significantly mitigate the risk of supply shortages, which are particularly detrimental in sports settings where the health and performance of athletes are on the line. By ensuring that the right supplies are at the right place at the right time, SPD supports the broader goals of sports medicine to enhance athletic performance and ensure rapid recovery from injuries. In athletic programs and sports facilities continue to evolve, the adoption of sophisticated supply chain management models like SPD becomes imperative. Not only does it support clinical operations, but it also aligns with the strategic objectives of sports medicine in providing high-quality, efficient, and cost-effective care. Future research and development in this area should focus on customizing and optimizing SPD models to meet the unique challenges of sports medicine, ensuring that they contribute effectively to the health and success of athletes.

References

Abbas, K., Afaq, M., Ahmed Khan, T., & Song, W.-C. (2020). A blockchain and machine learning-based drug supply chain management and recommendation system for smart pharmaceutical industry. *Electronics*, *9*(5), 852.

Ahmad, F. (2022). Interactive neutrosophic optimization technique for multiobjective programming problems: an application to pharmaceutical supply chain management. *Annals of Operations Research*, *311*(2), 551-585.

Chu, Z. (2021). The application of SPD intelligent logistics system in medical consumables management. *Chinese Hospital Director*, *17*(14), 78-80.

Deng, X. T., Li, Y. C., & Sun, L. X. (2020). Application of SPD model in the fine

management of medical consumables. *Jiangsu Health Business Management*, *31*(06), 796-799.

Elanor, R. (2023). Understanding the role of gut microbiota in regulating the immune response and disease resistance in farmed fish: An numerical study using next-generation sequencing. *FishTaxa-Journal of Fish Taxonomy*, *27*.

Haial, A., Berrado, A., & Benabbou, L. (2020). Redesigning a transportation network: the case of a pharmaceutical supply chain. *International Journal of Logistics Systems and Management*, *35*(1), 90-118.

He, L. (2020). Optimization Model of Shortest Distribution Path Selection in Intelligent Logistics. Journal of Physics: Conference Series,

Kramarz, M., & Kmiecik, M. (2022). Quality of Forecasts as the Factor Determining the Coordination of Logistics Processes by Logistic Operator. *Sustainability*, *14*(2), 1013.

Laganà, I. R., & Colapinto, C. (2022). Multiple criteria decision-making in healthcare and pharmaceutical supply chain management: a state-of-the-art review and implications for future research. *Journal of Multi-Criteria Decision Analysis*, *29*(1-2), 122-134.

Li, C., Hai, J., Li, L., & Jiang, Y. (2021). Construction of SPD for hospital medical equipment system for hospital logistics. *Xinjiang Chinese Medicine*, *39*(06), 59-61.

Li, F. (2022). Logistics Distribution Path Optimization Algorithm Based on Intelligent Management System. *Computational Intelligence and Neuroscience*, *2022*.

Ma, Y., Chen, Z., & Teng, T. (2022). Application of intelligent logistics distribution scheme of operating room consumables based on SPD management model. *Nursing and Rehabilitation*, *21*(01), 58-60+64.

Papalexi, M., Bamford, D., Nikitas, A., Breen, L., & Tipi, N. (2021). Pharmaceutical supply chains and management innovation? *Supply Chain Management: An International Journal*, *27*(4), 485-508.

Riaz, M., Riaz, M., Jamil, N., & Zararsiz, Z. (2022). Distance and similarity measures for bipolar fuzzy soft sets with application to pharmaceutical logistics and supply chain management. *Journal of Intelligent & Fuzzy Systems*, *42*(4), 3169-3188.

Tang, L. (2023). Integration and Application of Blockchain Technology and SPD Model in the Management of Medical Consumables. Industrial Engineering and Applications: Proceedings of the 10th International Conference on Industrial Engineering and Applications (ICIEA 2023), April 4-6, 2023, Phuket, Thailand,

Tang, W., Shi, W., Lu, C. M., & Chen, T. (2020). Risk control of medical consumables logistics management process based on SPD model. *China Market*, *01*, 172-173.

Tayyab, M., Awan, M. U., Bukhari, N. I., & Sabet, E. (2022). Key determinants of quality in the pharmaceutical supply chain. *International Journal of*

Quality & Reliability Management, *39*(2), 345-366.

Tsai, Y. X. (2021). Logistics management process optimization strategy based on SPD model. *National Circulation Economy*, *34*, 3-6.

Wang, M., & Jie, F. (2020). Managing supply chain uncertainty and risk in the pharmaceutical industry. *Health services management research*, *33*(3), 156-164.

Wang, Z. (2022). Evaluation and Analysis of Intelligent Logistics Distribution Using the Expectation-Maximization Algorithm Calculation Model. *Mathematical Problems in Engineering*, *2022*.

Yao, C. (2020). Research on logistics distribution path analysis based on artificial intelligence algorithms. *International Journal of Biometrics*, *12*(1), 100-108.

Zhang, B. B., Li, C. W., & Xiao, F. (2022). Practice of in-hospital drug logistics extension service based on SPD supply and procurement platform. *Chinese Journal of Health Information Management*, *19*(05), 724-727+744.