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Pharmaceutical Logistics Center Location in the Context of Centralized Medicine Procurement: A Literature Review

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Abstract. Centralized medicine procurement has become common worldwide to reduce drug prices and expenses. The logistics center is the core of the entire supply chain. The successful location of a logistics center can accelerate the efficiency of product distribution, reduce logistics costs, and bring convenience and economic benefits to both supply and demand. Pharmaceutical logistics differs from many other industries due to the nature of pharmaceutical products. This literature review followed the criteria and procedures outlined in the PRISMA systematic evaluation guidelines. We conducted a content analysis of 57 PubMed, Scopus, and Web of Science English papers. And six main research themes were identified: (1) Centralized medicine procurement; (2) Logistics center location methods; (3) Pharmaceutical logistics center site selection; (4) Pharmaceutical intelligent logistics; (5) Green pharmaceutical logistics (6) Pharmaceutical reverse logistics. Then, each theme's limitations and research gaps are reviewed and discussed, and finally, a detailed future research agenda is

proposed for the 14 specific research themes. This extensive and specific future research program provides an important opportunity for researchers to contribute to the location of the pharmaceutical logistics center.

Keywords: centralized medicine procurement, review, low carbon emission, pharmaceutical logistics center

1. Introduction

In recent years, drug prices have risen, and the share of people's healthcare expenditures has increased. Even in wealthy countries, drug shortages make getting the medicines harder. The COVID-19 pandemic made this problem worse. A sample of OECD countries said shortage alerts increased by 60% between 2017 and 2019. In OECD countries, healthcare spending has typically outpaced economic growth for the last 20 years. Moreover, the latest OECD estimates suggest that health spending will reach 11.3% of GDP by 2030 if costs are not adequately controlled (Chapman et al., 2022). Globally, getting access to necessary medications has become extremely difficult. Even high-income nations with socially-based health care systems find it more challenging to pay for the high cost of medications (Bero et al., 2015). Without good drug policies, the accessibility, affordability, efficacy, quality, and efficiency of healthcare services continue to impair the ability of health systems to function (Sharma & Gupta, 2013). It may be challenging for each country to resolve problems on its own. Discussions on the potential for greater cooperation between European nations are becoming more frequent (BARRETT, 2021). New initiatives include greater pricing transparency and increased collaboration—for instance, centralized procurement and price negotiations (Minghui et al., 2020). Centralized purchasing groups negotiate with upstream pharmaceutical firms to secure substantial discounts by centralizing large purchases, lowering drug procurement prices, and improving access to affordable medicines (Bastani et al., 2020). Centralized medication procurement has spread worldwide as a popular method of lowering drug costs and pricing (Dylst et al., 2011; Seidman & Atun, 2017).

Centralized procurement (also called pooled procurement) includes group procurement, regional procurement within countries, or centralized procurement at the national level. In addition, several countries may carry out centralized procurement jointly and may be coordinated or supported by international organizations (e.g., WHO, UNICEF). The aim is to decrease the cost of pharmaceuticals by exchanging "quantity" for "price," reducing the burden of living, and improving the population's health. The objectives of centralized procurement also include improving drug quality, reducing or eliminating corruption in procurement, improving fairness among procurement partners, improving supply chain management, strengthening the role of centralized procurement entities, and improving access to medicines (Vogler et al., 2021). Centralized purchasing is

frequently employed in Italy and Spain to increase market dominance and lower hospital management costs (Cappellaro et al., 2009). Notable cross-border procurement partnerships in the pharmaceutical sector include the GCC Group Procurement Program (Hasan & Lessing, 2015) and the Baltic Sourcing Initiative (Vogler et al., 2020).

The development of China's drug procurement model can be roughly described according to the logic from decentralization to integration: before 2000, decentralized procurement by medical institutions was the main mode; since 2000, centralized bidding and procurement of drugs by provinces have become the main mode, but the implementation of the "quantity-based" requirement was not effective; in 2018, the National Health Insurance Administration was established, which became a milestone event for the national organization of centralized quantity-based procurement of drugs. In 2019, China launched volume-based procurement. In the same year, China implemented the first phase of the National Centralized Drug Procurement (NCDP) pilot program. The "4+7" policy refers to the first round of NCDP pilots (four municipalities and seven sub-provincial cities in China were chosen as pilot cities in the first phase of the NCDP pilot). In January 2021, the "Opinions of the General Office of the State Council on Promoting the Normalization and Institutionalization of the Centralized Quantity Procurement of Drugs" was released, marking the shift from pilot to normalization of China's drug collection and procurement. As of July 2021, China has completed five batches of centralized procurement practices for drugs, with a typical price cut of approximately 55.6% for the selected drugs and annual savings of more than 50 billion yuan in medical costs. China's NCDP has achieved significant price reduction and cost control effects and promoted the reform goal of "exchanging quantity for price and squeezing out inflated price levels" in China's drug procurement.

In the context of centralized medicine procurement, the growing global demand for pharmaceutical supply chain management requires complex worldwide procurement and distribution networks and various modes of transportation (Agyekum, 2012).In a centralized system, logistics must be efficient and well-organized to ensure that the appropriate goods are delivered to the appropriate location at the proper time. In addition, Storage and transportation require higher requirements (Handfield, 2012a). Suppliers of supply chain services must follow all applicable regulations and maintain the highest level of accountability (Isom & Solutions, 2006). A logistics center is a specific area used for storing and distributing goods. Commercial operators carry out all logistics, transportation, and distribution of goods-related activities, including domestic and international transport. The correct location of the logistics center is critical to get the best solution for the nation's logistics system (Battal, 2020). The location of the logistics center not only affects how well operational activities go (Tu et al., 2010) but also

determines the management of the supply chain and the planning of the transportation network, which ultimately affects the entire distribution system (Melo et al., 2009; Pasagic Skrinjar et al., 2012). Successful logistics center site selection can accelerate product distribution efficiency, lower the cost of logistics, and bring convenience and economic benefits to both supply and demand.

Pharmaceutical logistics is unlike other industries. Pharmaceuticals are vulnerable to contamination, theft, or counterfeiting, which can threaten public safety (Ahmadi et al., 2020; Bansal et al., 2013). There has yet to be a literature review examining the siting of pharmaceutical logistics centers in the context of centralized medicine procurement. Good siting of pharmaceutical logistics centers is critical for policymakers and planning managers seeking to enhance the efficiency of the health system and maximize population health outcomes. In summary, given the high expenditure on pharmaceuticals, their significance to effects on population health, and the importance of logistics centers' location in the supply chain system. The purpose of this literature review is to answer the following two questions:

(1) The advantages and importance of centralized medicine procurement；

(2) From the logistics perspective, what should pharmaceutical logistics centers focus on in the context of centralized medicine procurement?

2. Methods

We first looked at three scientific databases, PubMed, Scopus, and Web of Science, for important empirical papers about centralized medicine procurement and pharmaceutical logistics. Use these strings to do the search: "medicine Logistics center location" OR "Location of pharmaceutical logistics center" OR" Location of pharmaceutical logistics center" OR "medicine distribution center location" OR" pharmaceutical logistics center site selection "OR" Pharmaceutical Intelligent Logistics" OR" Green Pharmaceutical Logistics" OR" Pharmaceutical reverse logistics" AND "medicines collective procurement" OR "centralized medicine purchasing" OR "Centralized Pharmaceutical Procurement" OR "Centralized Drug Procurement" OR "centralized drug purchasing" OR "collective drug procurement." Keywords, article titles, and abstracts were the search fields for all three scientific databases. We did not limit our range of publications at a particular time, trying to capture as many publications as possible. The number of articles retrieved in each database is 136 from Pubmed, 1450 from Scopus, and 530 from Web of Science. Use Zotero as reference management software to organize references and check for duplications. After removing duplicates, we got 1189 articles. This literature review used the criteria and procedures outlined in the PRISMA systematic evaluation guidelines (E&E, 2015). Figure 1 shows the flow chart for selecting the publications included in this literature review.

Table 1 shows the inclusion and exclusion criteria for the articles. After the screening, 52 papers remained. Snowballing was conducted based on the previously filtered results (5 papers) following PRISMA. The inclusion and exclusion criteria were identical to those previously adopted. This procedure resulted in a dataset containing 57 papers. Each paper in the dataset was evaluated based on Table 1 criteria.

3. Results

The full list of references that met the requirements for inclusion is in Tables 2, 3, and 4. For illustrative purposes, the literature in tables 2, 3, and 4 were analyzed and classified, and the paper analysis results are illustrated with figures and text in sections 3.1–3.3.

3.1. Medicine centralized purchasing

Among these 18 papers on centralized medicine procurement, the countries involved are Italian, Portugal, China, Brazilian, Colombia, Iran, India, Mexican, and Jordan.

In 2019, China launched volume-based purchasing (VBP), and the VBP pilot has positively reduced overall drug spending and increased the use of approved generics in three pilot cities. This general trend was not observed in the two non-pilot cities (Y. Chen et al., 2021). The "4+7" policy implemented in the same year has promoted the substitution of domestic generic drugs for originator drugs, lowered the prices of various drugs, and improved the accessibility of policy drugs (L. Chen et al., 2020; Long et al., 2022; N. Wang et al., 2021; Wen et al., 2021; Y. Yang et al., 2022). Established the State Health Procurement Committee (EPY) in Greece has encouraged cost savings through centralized medicine purchasing (Kastanioti et al., 2013). Nine Caribbean islands reduced unit drug costs by more than 50% with the help of centralized medicine procurement policies (HUFF-ROUSSELLE & BURNETT, 1996). In Jordan, centralized medicine procurement has resulted in an estimated 8.9% savings in drug costs (Al-Abbadi et al., 2009). Centralized medicine procurement has also led to lower drug prices in these countries: Columbia (Perez et al., 2019)、Portugal (Vogler, Habimana, et al., 2022)、Brazilian (Alexandre et al., 2014; Moraes et al., 2016)、Iran (Bastani et al., 2020)、India (Talreja & Kalra, 2020)、Mexican (Adesina et al., 2013)、Jordan (Alabbadi, 2011). Centralized pharmaceutical procurement can also improve governance, transparency, equity, and medicine (Vogler, Bauer, et al., 2022; Wen et al., 2021). During the COVID-19 crisis, Centralized intercountry procurement of vaccines and medicines also played an important role.

In summary, the literature on centralized medicine procurement focuses on cost control effects. Some literature describes centralized purchasing organizations' role, rationale, and influencing factors in reducing drug prices (Greer et al., 2020; A.

Huang et al., 2022; Klasa et al., 2018; McSorley, 2007; van de Ven & Schut, 2008). Studies examine the impact of centralized medicine purchasing practices on corporate net profits (Carpenter, 2007; DANZON, 1997; Danzon et al., 2015; Q.-S. Wang et al., 2021; Wing et al., 2018). Some scholars have found that centralized medicine purchases increase business or supply chain costs, with transportation costs rising by 54%, some overhead costs increasing by 30%, labor costs increasing by 88.9%, and warehouse insurance costs increasing by 71.85% in 2016 over 2015 (Bastani et al., 2020). China's centralized drug procurement policy is beginning to have a detrimental effect on corporate net profits. (Hua et al., 2022). If centralized medicine procurement does not bring sufficient cost savings to companies, price competition will lead to lower profit margins. Decreased corporate profitability can lead to unsustainable policies, so policy support is needed to reduce corporate costs. The importance of centralized medicine procurement should also be reflected in improving the efficiency of the pharmaceutical supply chain and promoting the realization of a win-win situation for all parties. No literature analyzes centralized medicine procurement from a logistics perspective. Thus, the following questions need further attention:

(1) How to choose the location of the pharmaceutical logistics center in the context of centralized medicine procurement?

(2) Logistics perspective to identify the gaps that need more attention.

Table 1: Overview of the inclusion and criteria

Inclusion criteria	
1	Articles in academic journals
2	Papers that clearly describe the datasets and sample size
3	Papers providing the detection results in terms of accuracy
4	Be original investigations of interventions that are published in peer-reviewed journals.
5	Reporting on the effects of an actual intervention
6	Postgraduate Theses
Exclusion criteria	
1	Just the abstract is accessible for papers
2	Duplicate records
3	Non-English text
5	Non-academic text
6	Report results from a computer model or simulation
7	Book reviews

Table 2: Literature on medicine centralized purchasing

Effects	Country	Author and Year	Research Content
Negative	China	(Hua et al., 2022)	The negative impact of the policy on the net profit of the company began to appear gradually
	Iran	(Bastani et al., 2020)	Significant increase in personnel costs, overheads, and warehouse costs
	Portugal	(Vogler, Habimana, et al., 2022)	Improved governance and equity
	Brazilian	(Alexandre et al., 2014)	Improving access to medicines
		(Moraes et al., 2016)	Lower prices for purchased drugs and higher purchasing power for the government
	Iran	(Bastani et al., 2020)	Lower drug prices, higher patient satisfaction
	Colombian	(Perez et al., 2019)	Prices of drugs used to treat hepatitis C fell by more than 90% overall
	India	(Chaudhury et al., 2005)	It can save nearly 30 percent of drug costs and improve drug use and accessibility
		(Talreja & Kalra, 2020)	Medication costs approximately 1.9-2.5 times less than retail.
Positive	Italian	(Baldi & Vannoni, 2017)	Save sixty percent of the price paid
	Mexican	(Adesina et al., 2013)	Prices of antiretroviral drugs fell by an average of 38% after the first round of centralized purchasing
	Jordan	(Alabbadi, 2011)	Lowering drug prices and improving drug accessibility
	China	(Long et al., 2022)	Significant price reductions for winning drugs
		(N. Wang et al., 2021)	The entire policy-related medications' Drug Price Index declined considerably
		(Y. Yang et al., 2022)	Promote the use of domestic generic drugs, reduce drug prices, and ease the burden of drug use
		(L. Chen et al., 2020)	All types of drug prices have decreased
		(Wen et al., 2021)	Policy drug accessibility improved
		(Y. Chen et al., 2021)	Lower overall drug spending and increased generic recognition in pilot cities

3.2. Location of logistics center methods

The logistics center is the backbone of the logistics structure and the coordination center for various economic activities such as procurement, production, storage, and transportation. Integrating different modes of transportation and consolidating goods supports effective and efficient freight transportation throughout the logistics network (Rikalović et al., 2018).

The efficiency of a logistics system depends to a large extent on its location. Correctly placing logistics centers is a critical strategic decision for optimizing the transportation network (Milosavljević et al., 2018). Reasonable distribution center location can shorten distribution routes, increase distribution efficiency, lower distribution costs, coordinate the logistics of production and consumption, and consider the logistics system's balanced growth (X. L. Liu & Zhang, 2013). Conversely, unfavorable locations may incur additional costs (Kayikci, 2010). Efficiency in logistics and transportation plays a key role in determining the customer experience. Storage, transit, distribution, and processing are essential in logistics and transportation (L. Yang & Song, 2022).

However, logistics center site selection decisions are expensive, difficult to undo, and have a protracted effect. Any parameter of the problem (cost, demand, or distance) can fluctuate significantly while the siting decision is in effect. Inaccurate parameter estimations might also result from flawed measurements or tasks that are part of the modeling process (e.g., aggregating demand points and selecting distance parameters) (Snyder, 2006). Recognizing this, scholars have been studying the logistical center site selection. The siting problem was first proposed by Weber, and the object of the siting study was the location of the warehouse, intending to minimize the total transport distance between the warehouse and each use (Weber, 1962). Site selection theory has developed rapidly in recent years.

Quantitative and qualitative methods are the two primary branches of traditional mathematics. Qualitative methods are more subjective and prone to error. In contrast, quantitative methods can be described as specific mathematical formulas with high accuracy and are often used in practice in combination with qualitative and quantitative methods. Since the logistics center siting problem involves many variables and constraints, it is a typical NP-hard problem. Many scholars have researched the location problem of non-convex and nonlinear programming with complex constraints and proposed various solutions. Among these, intelligent optimization algorithms have yielded positive results. Table 3 depicts common site selection methods.

As illustrated in Table 3. Qualitative analysis is a prediction method in which professionals in the relevant field analyze the characteristics of a problem and speculate on the future condition and development trend based on their experience and knowledge. The disadvantage is that it lacks objective criteria, and the

forecasting process is based on expert experience and subjective judgment, which makes reaching a unified conclusion difficult and less reliable. The quantitative analysis method is scientific. However, many non-measurement factors cannot be considered.

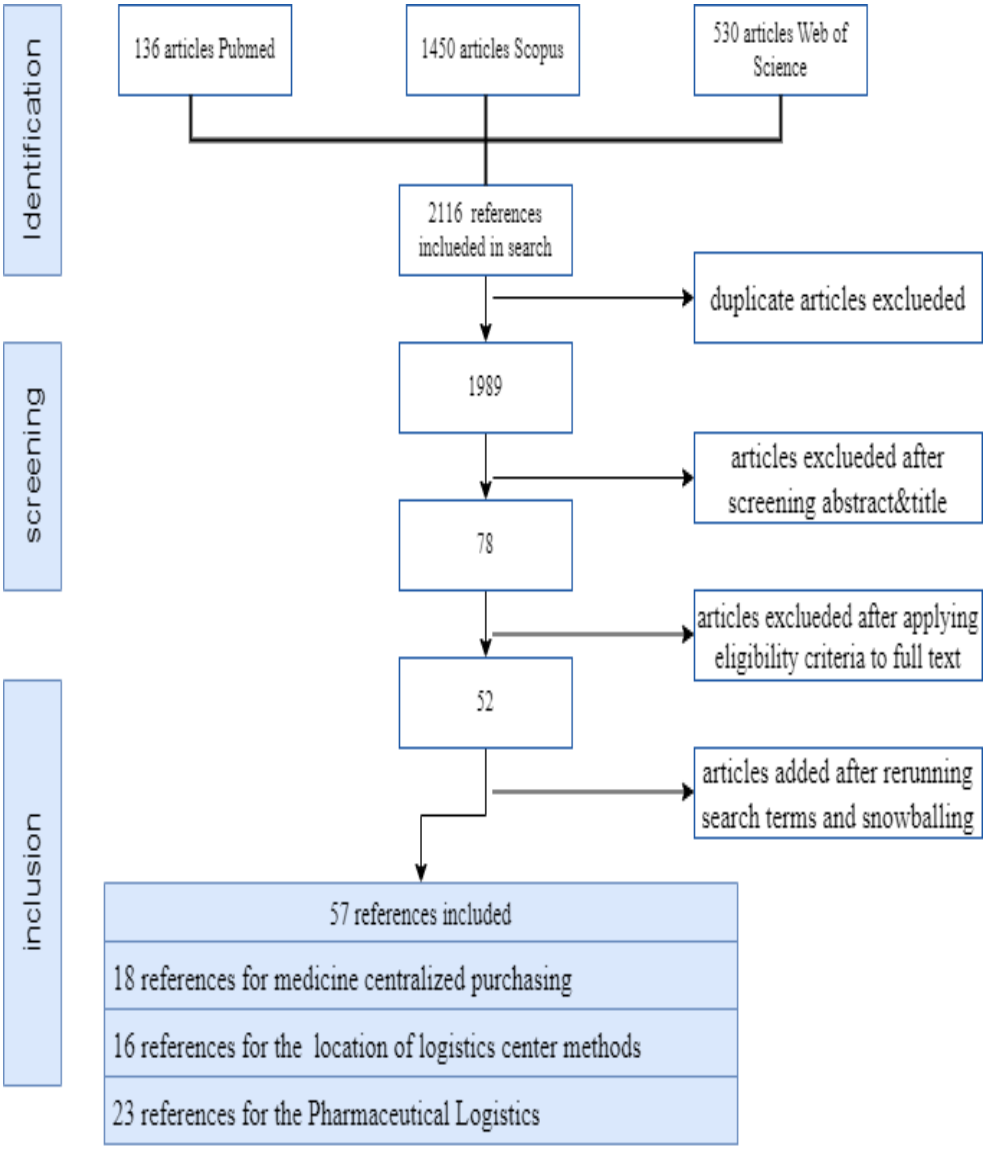

Fig. 1: Flowchart of the Selection of the publications included in the literature review

Moreover, it is difficult to apply this method when the data is insufficient, or the analyst is weak in mathematics. Calculations can also be cumbersome. Intelligent optimization algorithms (as shown in Table 3) are developed by simulating or

revealing certain phenomena and processes in nature or the intelligent behavior of a population of organisms; they are simple, general, and easy to process in parallel. The disadvantage is that most algorithms are sensitive to parameter selection, which may affect the accuracy of the results. Some algorithms require idealized or simplified assumptions that do not correspond to reality. Some algorithms cannot converge to an optimal global solution and may instead fall into a local optimum. Even though the optimal global solution can be found, the convergence speed is extremely slow.

Most of the current research has improved the algorithm. Binary particle swarm optimization is effective and robust for solving complex optimization problems (Lin & Guan, 2018). However, the results were not good when the data increased. There is still a need for better ways to improve the siting of logistics centers. This study built the multiattribute group decision-making method framework with excellent robustness and superior performance (P. Liu & Li, 2020). The disadvantage is that the method specifies the expert weight information, and there needs to be a specialized method or model to calculate the weights, which may affect the accuracy of the results. A Delphi-Fuzzy-TOPSIS model was developed in a different study that is acceptable for complex decision-making and must consider various factors in the context of hazy assessments. However, the method is inappropriate for other forms of value such as real numbers or interval numbers (Pham et al., 2017). There are many cases where the site selection method has been improved but still has flaws (Cavusoglu et al., 2022; Lv & Sun, 2022; Tong & Cheng, 2022a; H. Wang et al., 2022; Yuan & Gao, 2022).

In general, the current logistics center siting methods are subjective, assumptions are out of touch with reality, and calculation results are unrealizable. The complexity, changeability, and growth of the center location problem make it necessary to develop new location models and ways to solve it. This can lead to the following problems:

(1) Optimized logistics center site selection model;

(2) Integrated optimization problem of logistics location-inventory-routing problem.

Table 3: Literature on logistics center location methods

	Name of algorithm	Advantages	Disadvantages
Qualitative Methods	Analytic hierarchy process (Kumar & Pant, 2023)	capture subjective outlook of associated problems.	highly subjective
	Delphi method (Sterling et al., 2023)	can handle complex, uncertain problems	time-consuming, subjective,
	Fuzzy comprehensive evaluation method (W. Zhang et al., 2021)	analyzing fuzzy problems	shortcomings in solving problems like weight calculation
Quantitative Methods	Gravity method (Kong et al., 2010)	greater flexibility, simple model	assumes a linear relationship
	Factor score method (Dang et al., 2022)	can reduce the dimensionality of the data	assume a normal distribution, linear relationship, and sensitivity to missing data
	Mixed-integer programming method (Alves & Clímaco, 2007)	handle complex and large-scale problems	assume convex functions, sensitive to the initial solution
	Coverage model (Xu et al., 2022)	handle large amounts of spatial data	assume uniform distribution
	P-median model method (Taleshian & Fathali, 2016)	robustness concerning outliers, the accommodation of a diverse range of similar data.	assumes the demand points are fixed and known; assumes the demand is evenly distributed
intelligent optimization algorithms	Genetic algorithm (Jiacheng & Lei, 2020)	high global search capability, robustness	easy to fall into local optimum; sensitive to parameters
	Particle swarm algorithm (Jiang et al., 2021)	rapid searching speed, good initial convergence,	slow convergence and the optimum local problems
	Flower pollination algorithm (Chiroma et al., 2015)	has the ability to search the entire search space and is not prone to get trapped in local optima	sensitive to the choice of control parameters, does not have a global convergence guarantee
	Wolf swarm algorithm (Zheng, 2022)	shown good global convergence and computational robustness in complex high-dimensional functions	the number of iterations and convergence speed need to be further improved
	Whale Optimization Algorithm (L. Liu & Zhang, 2022)	the process is simple, and the convergence speed is fast	insufficient global search ability and easily falling into the local optimum
	Simulated annealing algorithm (Almarashi et al., 2020)	can escape local minima	slow convergence, easy to fall into local optimum， dependent on the choice of the initial settings
	Ant colony algorithm (Li et al., 2022)	good optimization results for smaller TSP problems	slow convergence, easy to fall into local optimum
	Bald eagle search algorithm (Tong & Cheng, 2022b)	good global search ability	can be prone to get stuck in local optima

3.3. Pharmaceutical logistics

Due to the difficulty of drug quality control, distribution timeliness, and high technical content, traditional and cold chain logistics can hardly meet the standard requirements of drug logistics (Handfield, 2012b). As a pharmaceutical supply chain hub and product distribution center, pharmaceutical logistics center site selection decisions and related pharmaceutical industry development are closely related. Pharmaceutical logistics center facilities are more important than integrated logistics centers (Jung et al., 2021).

The 23 papers in this section are divided into four categories: pharmaceutical logistics center site selection, intelligent pharmaceutical logistics center, green pharmaceutical logistics, and reverse pharmaceutical logistics. They will be discussed in 3.3.1–3.3.4.

3.3.1. Pharmaceutical logistics center site selection

Despite the irreplaceable nature of pharmaceutical logistics centers, studies have yet to be conducted to address their siting. The main limitations of the literature in this area are: considering only some pharmaceutical products (Y. Yang et al., 2021; Yuan & Gao, 2022) or vaccines (Desticioglu & Ozyoruk, 2022) , only for a particular pharmaceutical company (Jalal et al., 2022; Sekar, 2010). Selecting an existing logistics center (Mete & Zabinsky, 2010) as a backup in case of an unexpected disaster or building a new logistics center (Jia et al., 2007). Therefore, further attention needs to be paid to the following issues:

(1) In the context of centralized medicine procurement, how to reasonably layout pharmaceutical logistics center locations in view of the multiple types of drugs, multi-enterprise participation, and uncertainty of suppliers?

(2) Incorporate predictions of future disasters for alternative pharmaceutical logistics centers into site selection factors.

3.3.2. Pharmaceutical intelligent logistics

With the development of intelligent logistics and the introduction of related policies, intelligent logistics technologies to improve supply chain resilience, transparency, and trust have gradually become the focus of government and society. Some researchers also focus on this aspect (Alzawamri et al., 2022; Hu et al., 2023; Lee, 2021; P & Chandrasekaran, 2022; Trautmann et al., 2022; P. Zhang et al., 2021). However, there needs to be more literature on intelligent pharmaceutical logistics. In centralized medicine procurement, the single supply source, the monopoly of buyers and sellers, may cause "bad money to drive out good money" (L. Chen et al., 2020) which leads to the following issues that require further attention：

(1) What problems are faced by pharmaceutical logistics centers in terms of intelligent logistics and how to deal with them?

(2) How to plan an intelligent pharmaceutical logistics center in the context of centralized medicine procurement?

3.3.3. Green pharmaceutical logistics

Green procurement is necessary for the pharmaceutical industry to ensure that the materials, product, services procured have as little negative impact on the environment and society as possible. (Dubey et al., 2017; Faisal, 2015). Despite the growing urgency to curb carbon emissions globally, the healthcare industry, particularly the pharmaceutical industry, has received insufficient attention (Belkhir & Elmeligi, 2019). Regarding green pharmaceutical logistics, most studies have focused on low-carbon issues in pharmaceutical manufacturing processes (Eckelman & Sherman, 2016; Miettinen & Khan, 2022; Wu et al., 2022)、pharmacies (Gahbauer et al., 2021) or reverse pharmaceutical logistics (Alizadeh et al., 2020; Ghannadpour et al., 2021; Govindan et al., 2022; Joneghani et al., 2022; Taslimi et al., 2020; Xie & Breen, 2012; Yao et al., 2020). Some studies have focused on giving policy recommendations (Z. Huang & Fu, 2020; Sabat et al., 2022; Song et al., 2022), and few have analyzed the issue from a logistics perspective. This has led to the following issues that need further attention：

(1) Research in the area of positive green pharmaceutical logistics for large-scale, multi-category pharmaceutical distribution；

(2) Research on positive pharmaceutical green logistics centers for large-scale, multi-category pharmaceuticals.

(1)

Table 4: Literature on pharmaceutical logistics

Research Highlights	Author, years	Main contents
Pharmaceutical logistics center site selection	(Yuan & Gao, 2022)	Multi-center site selection and path optimization for pharmaceutical logistics enterprises under dynamic uncertainty
	(Jalal et al., 2022)	Study the location of drug distribution centers and transportation decisions
	(Sekar, 2010)	Study of vehicle routing problems, number and possible locations of pharmaceutical distribution centers
	(Y. Yang et al., 2021)	Build models to select pharmaceutical logistics centers and plan pharmaceutical logistics distribution paths and inventory strategies to achieve scientific decision-making of the system
	(Desticioglu & Ozyoruk, 2022)	Vaccine distribution center site selection issues
	(Jia et al., 2007)	Optimize the location of medical supply facilities to respond to large-scale emergencies.
	(Mete & Zabinsky, 2010)	Development of stochastic planning methods for disaster preparedness
Pharmaceutical Intelligent Logistics	(Trautmann et al., 2022)	Blockchain technology can optimize the drug supply chain and reduce drug counterfeiting
	(P. Zhang et al., 2021)	A blockchain, cloud storage, and IoT-based cold chain supervision solution is proposed
	(P & Chandrasekaran, 2022)	A new approach to drug supply chain security information sharing is proposed
	(Hu et al., 2023)	Established an intelligent vaccine supply chain system
Green Pharmaceutical Logistics	(Shamsuzzoha et al., 2020)	Centralized supply chain systems can improve information flow, increase freight capacity and reduce CO2emissions
	(Z. Huang & Fu, 2020)	Three green logistics government subsidy strategies are proposed
	(Song et al., 2022)	Coordination issues in the green pharmaceutical supply chain
	(Sabat et al., 2022)	Investigate the current state of green supply chain management and its drivers and facilitators.
	(Han et al., 2019)	Research on low-carbon delivery of pharmaceuticals, using drones for “green delivery”

Pharmaceutical reverse logistics	(Taslimi et al., 2020)	Use the Periodic Load Related Capable Vehicle Pathway Problem to determine the least risky pathway arrangement for medical waste collection.
	(Govindan et al., 2022)	Medical waste management conversion model considering waste generation uncertainty to design the green inverse network to minimize total cost and population risk
	(Alizadeh et al., 2020)	A forward and reverse network model for medical supplies is proposed
	(Joneghani et al., 2022)	Solve the sustainable zone allocation problem in medical waste management
	(Xie & Breen, 2012)	Design a green pharmaceutical supply chain to reduce preventable pharmaceutical waste and effectively handle unavoidable pharmaceutical waste
	(Yao et al., 2020)	Medical waste treatment center site selection issues
	(Ghannadpour et al., 2021)	Route optimization of medical waste collection vehicles in Iran's small medical centers

3.3.4. How does intelligent healthcare impact green pharmaceutical logistics? How to establish a green pharmaceutical logistics center using intelligent healthcare？ Pharmaceutical reverse logistics

Pharmaceutical contamination results from the dispersal of some active pharmaceutical ingredients and endocrine-disrupting compounds in water and soil, which harms public health and the environment (Pereira et al., 2017). Due to the COVID-19 pandemic, health officials have recently made it mandatory for people to wear masks, gloves, and disinfectants to stay safe. This has led to more waste (C. Chen et al., 2021). So better hospital waste management is required (Xin, 2015). These studies illustrate the need for reverse logistics of pharmaceuticals and give some policy recommendations (da Silva et al., 2022; de Campos et al., 2021; Mohammed et al., 2021; Pereira et al., 2017; L. S. Wang et al., 2021). Few studies have examined recycling routes (Alizadeh et al., 2020; Ghannadpour et al., 2021; Govindan et al., 2022; Joneghani et al., 2022; Taslimi et al., 2020; Xie & Breen, 2012; Yao et al., 2020). This information leads to the following issues that require further attention:

(2) Pharmaceutical forward logistics still need more attention;

(3) Pharmaceutical reverse logistics center site selection issues;

How to play the role of intelligent logistics in reverse pharmaceutical logistics?

4. Conclusion

Centralized medicine procurement lowers prices, reduces costs, and improves drug accessibility. The location of logistics centers affects distribution costs and efficiency. Due to the difficulty of drug quality control, distribution timeliness, and high technology, traditional and cold chain logistics are challenging to meet the standard requirements of drug logistics, especially in centralized medicine procurement. The construction of a new pharmaceutical logistics center with a flexible supply chain for nationwide, multi-enterprise, multi-species, and high-volume centralized drug distribution has become a new research topic.

In reviewing the pharmaceutical logistics center siting in the context of centralized drug procurement, We conducted a content analysis of 57 selected English papers in PubMed, Scopus, and Web of Science. Moreover, six main research themes were identified: (1) Centralized medicine procurement; (2) Logistics center location methods; (3) Pharmaceutical logistics center site selection; (4) Pharmaceutical intelligent logistics; (5) Green Pharmaceutical Logistics (6) Pharmaceutical reverse logistics. Then, each theme's limitations and research gaps are reviewed and discussed, and finally, a detailed future research agenda is proposed for the 14 specific research themes. This broad and specific future

research agenda offers researchers a significant opportunity to contribute to the pharmaceutical logistics center siting field.

This paper's limitation is that we only chose English papers. However, centralized medicine procurement and pharmaceutical logistics centers are highly geographic areas with varying economic, social, and regulatory conditions in different countries. We might lose some of the insights of pharmaceutical logistics center location research in those non-English speaking countries. In addition, this paper is limited by the fact that there are fewer studies on the pharmaceutical logistics center location issue. Finally, social development is always faster than research publications. Therefore, in addition to drawing 14 research opportunities from existing published papers, we call for a broader collaboration between researchers and pharmaceutical logistics practitioners to facilitate future understanding and research on this critical topic.

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