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# BIBLIOMETRIC ANALYSIS OF PUBLICATIONS AND AUTHORS ON STOCHASTIC DEMAND INVENTORY MODELS IN PHARMACEUTICAL SUPPLY CHAINS

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## ABSTRACT

**Objectives:** The study aims to perform a bibliometric analysis of research on stochastic demand inventory models within pharmaceutical supply chains, focusing on identifying key trends, influential contributions, and collaboration networks that have shaped the field between 2018 and 2024.

**Theoretical Framework:** The analysis is grounded in the theory of inventory management under uncertainty, particularly in the context of the pharmaceutical industry, where demand variability presents significant challenges for supply chain optimization.

**Method:** A systematic review of 39 articles published between 2018 and 2024 was conducted. Keywords related to stochastic demand and pharmaceutical supply chain inventory management were used to select the studies. Bibliometric tools were employed to evaluate publication trends, citation counts, author collaboration networks, and emerging research topics.

**Results and Discussion:** The analysis revealed a concentration of research efforts on optimizing inventory levels to manage uncertain demand. Key authors in the field have contributed significantly, as reflected in high citation counts, establishing them as influential figures. The study also notes an increasing trend of interdisciplinary and international collaborations, along with the adoption of advanced stochastic modeling techniques.

**Research Implications:** The findings suggest that further research should continue exploring interdisciplinary approaches and advanced modeling techniques, as these areas show potential for practical advancements in managing pharmaceutical supply chains under uncertainty.

**Originality/Value:** This study offers a focused bibliometric analysis of the recent developments in stochastic demand modeling for pharmaceutical supply chains. Its value lies in highlighting current research trends, identifying influential contributors, and offering insights into future directions, making it a useful reference for researchers and practitioners in the field.

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## ANÁLISE BIBLIOMÉTRICA DE PUBLICAÇÕES E AUTORES SOBRE MODELOS DE ESTOQUE COM DEMANDA ESTOCÁSTICA EM CADEIAS DE SUPRIMENTOS FARMACÊUTICAS

**RESUMO**

**Objetivos:** O estudo tem como objetivo realizar uma análise bibliométrica da pesquisa sobre modelos de estoque com demanda estocástica em cadeias de suprimentos farmacêuticas, com foco em identificar tendências-chave, contribuições influentes e redes de colaboração que moldaram o campo entre 2018 e 2024.

**Referencial Teórico:** A análise é baseada na teoria da gestão de estoques sob incerteza, particularmente no contexto da indústria farmacêutica, onde a variabilidade da demanda apresenta desafios significativos para a otimização da cadeia de suprimentos.

**Método:** Foi realizada uma revisão sistemática de 39 artigos publicados entre 2018 e 2024. Palavras-chave relacionadas à demanda estocástica e gestão de estoques na cadeia de suprimentos farmacêutica foram usadas para selecionar os estudos. Ferramentas bibliométricas foram empregadas para avaliar tendências de publicação, contagem de citações, redes de colaboração entre autores e tópicos emergentes de pesquisa.

**Resultados e Discussão:** A análise revelou uma concentração de esforços de pesquisa na otimização dos níveis de estoque para lidar com a demanda incerta. Autores-chave no campo contribuíram significativamente, refletido em altos números de citações, estabelecendo-os como figuras influentes. O estudo também observa uma tendência crescente de colaborações interdisciplinares e internacionais, além da adoção de técnicas avançadas de modelagem estocástica.

**Implicações para a Pesquisa:** Os resultados sugerem que pesquisas futuras devem continuar explorando abordagens interdisciplinares e técnicas avançadas de modelagem, pois essas áreas mostram grande potencial para avanços práticos na gestão de cadeias de suprimentos farmacêuticas sob incerteza.

**Originalidade/Valor:** Este estudo oferece uma análise bibliométrica focada nos desenvolvimentos recentes da modelagem de demanda estocástica em cadeias de suprimentos farmacêuticas. Seu valor reside em destacar as tendências atuais de pesquisa, identificar contribuintes influentes e oferecer insights sobre direções futuras, tornando-se uma referência útil para pesquisadores e profissionais da área.

**Palavras-chave:** Técnicas Avançadas de Modelagem, Análise Bibliométrica, Redes de Colaboração, Gestão de Estoques, Cadeia de Suprimentos Farmacêutica, Demanda Estocástica.

## ANÁLISIS BIBLIOMÉTRICO DE PUBLICACIONES Y AUTORES SOBRE MODELOS DE INVENTARIO CON DEMANDA ESTOCÁSTICA EN CADENAS DE SUMINISTRO FARMACÉUTICAS

**RESUMEN**

**Objetivos:** El estudio tiene como objetivo realizar un análisis bibliométrico de la investigación sobre modelos de inventario con demanda estocástica en las cadenas de suministro farmacéuticas, centrándose en identificar tendencias clave, contribuciones influyentes y redes de colaboración que han dado forma al campo entre 2018 y 2024.

**Marco Teórico:** El análisis se basa en la teoría de la gestión de inventarios bajo incertidumbre, particularmente en el contexto de la industria farmacéutica, donde la variabilidad de la demanda presenta importantes desafíos para la optimización de la cadena de suministro.

**Método:** Se realizó una revisión sistemática de 39 artículos publicados entre 2018 y 2024. Se utilizaron palabras clave relacionadas con la demanda estocástica y la gestión de inventarios en la cadena de suministro farmacéutica para seleccionar los estudios. Se emplearon herramientas bibliométricas para evaluar tendencias de publicación, recuento de citas, redes de colaboración entre autores y temas emergentes de investigación.

**Resultados y Discusión:** El análisis reveló una concentración de esfuerzos de investigación en la optimización de los niveles de inventario para gestionar la demanda incierta. Los principales autores del campo han contribuido significativamente, como lo reflejan los altos recuentos de citas, lo que los establece como figuras influyentes. El estudio también señala una tendencia creciente hacia colaboraciones interdisciplinarias e internacionales, junto con la adopción de técnicas avanzadas de modelado estocástico.

**Implicaciones para la Investigación:** Los hallazgos sugieren que la investigación futura debe continuar explorando enfoques interdisciplinarios y técnicas avanzadas de modelado, ya que estas áreas muestran un gran potencial para mejoras prácticas en la gestión de cadenas de suministro farmacéuticas bajo incertidumbre.

**Originalidad/Valor:** Este estudio ofrece un análisis bibliométrico enfocado en los desarrollos recientes en la modelización de demanda estocástica para cadenas de suministro farmacéuticas. Su valor radica en destacar las tendencias de investigación actuales, identificar a los contribuyentes influyentes y ofrecer perspectivas sobre futuras direcciones, convirtiéndose en una referencia útil para investigadores y profesionales del campo.

**Palabras clave:** Técnicas Avanzadas de Modelado, Análisis Bibliométrico, Redes de Colaboración, Gestión de Inventarios, Cadena de Suministro Farmacéutica, Demanda Estocástica.

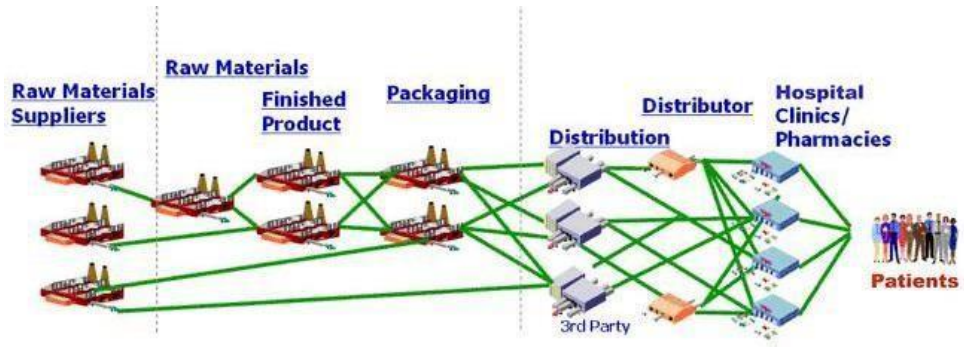
## 1 INTRODUCTION

Efficient management of pharmaceutical supply chains is a key aspect in the supply systems of health- related products, allowing for the satisfaction of medicine demand at the lowest possible cost and freeing valuable resources for other uses. Stochastic inventory models enable optimal decision-making regarding when and how much to order under random demand conditions. These models consider system-specific constraints such as ordering costs, acquisition, scarcity, storage, transportation, among others. Unlike industrial management, the service level in drug supply must be kept as high as possible to provide timely treatment to patients (1; 2; 3; 6; 9).

In most of the supply of pharmaceuticals to public pharmacies (FPs) in world is managed through a central warehouse, which is supplied by external providers. Central warehouse acts as an intermediary between providers and FPs, receiving demand from end-users. The supply chain for private pharmacies (FPRs) is broader, potentially including the production process, storage, and distribution to primary or secondary warehouses, and then to pharmacies. Figure 1 presents a global scheme of the pharmaceutical supply chain in the private sector. Although there is experience in bibliometric analysis of supply chains and stochastic inventory models (9), the focus of these studies has not been on the particularities of the pharmaceutical sector.

**Figure 1**

*General supply chain in the FPRs system.*



## 2 METHODOLOGY

The bibliographic review was conducted in three main stages: planning and collecting bibliographic records, studying the literature, and performing bibliometric analysis. The planning and collection stage involved determining how to obtain references necessary to answer the research questions. Searches were conducted in the Web of Science (WoS) and Scopus databases to gather a set of publications related to stochastic demand inventory models applied to pharmacies.

Search terms included “lot-siz”, ”inventor”, ”replenish”, ”stochast”, ”random demand”, ”fore- cast”, ”uncertain demand”, ”drug”, and ”pharma”. The inclusion criteria focused on articles about pharmaceutical inventory management with stochastic demand applied to pharmaceutical supply chains from 2018 onwards. Exclusion criteria eliminated articles without application to pharmacy, pure demand prediction studies, unrelated inventory models, reviews without applications, and those not considering stochastic demand.

The initial search identified 71 articles. After applying the exclusion criteria, 39 articles remained for detailed analysis. These articles were saved in BibTeX format and analyzed using R-project software for bibliometric analysis, exploring publications per year, citations, author collaboration networks, research trends, and more. Figure 2 summarizes the methodology considered in this work.

## 3 BIBLIOMETRIC ANALYSIS

We performed a bibliometric analysis of the 39 documents reviewed. Table 1 show selected citations and descriptions.

**Table 1**

*Citations and descriptions*

| Author | Description |
|---|---|
| Chen et al., 2019 | Implementing Green Supply Chain Management for Online Pharmacies through a VADD Inventory Model |
| Rojas et al., 2022 | Modeling Inventory Cost Savings and Supply Chain Success Factors: A Hybrid Robust Compromise Multi-Criteria Approach Suhandi et al., |
| 2023 | Closed-loop supply chain inventory model in the pharmaceutical industry toward a circular economy |
| Gong et al., 2023 | Bandits atop Reinforcement Learning: Tackling Online Inventory Models with Cyclic Demands Saha et al., |
| 2019 | Modelling and analysis of healthcare inventory management systems |
| Bialas et al., 2020 | Improving hospital pharmacy inventory management using data segmentation |
| Siegert et al., 2020 | Addressing the use and end-of-life phase of pharmaceutical products in life cycle assessment |
| Schulte et al., 2022 | Modeling the use and end-of-life phase of pharmaceuticals in support of a life cycle inventory analysis - Case study on different antibiotics in Germany |
| Jobira et al., 2022 | Assessment of Knowledge, Practices, and Challenges of Pharmaceuticals Inventory Control Among Pharmacy Professionals Working in Selected Public Health Facilities of West Arsi Zone, Oromia, Ethiopia Jaju et al., 2023 Inventory |
| Control Mechanism of the Pharmacy Store of a Recently Established National Institute in Eastern India: A Cross-Sectional, Investigative Analysis | |
| Huizen et al., 2018 | Inventory Control System for Vaccines Distribution With Model Predictive Control In Hospital Liu et al., |
| 2024 | Performance evaluation for the IoT-based manufacturing system in pharmacy industry |
| Johari et al., 2021 | Socially concerned periodic review replenishment system with customer service level and supply chain contracting |

Grunder et al., 2019 A hybrid Genetic Algorithm approach to minimize the total joint cost of a single-vendor multi-customer integrated scheduling problem Xu et al., 2021
The Study of Irregular Demand Forecasting for Medicines: The Case Study of ABC Medical Center Hospital
Lopes et al., 2019 Use of Monte Carlo simulation in stock management for pharmaceutical companies
Costa et al., 2024 Effect of applying a demand forecasting model to assess the accuracy of inventory management in a specialty pharmacy Bozorgi et al.,
2021 Transforming the vaccine supply chain in Australia: Opportunities and challenges
Fisher et al., 2018 User-centered design and usability testing of RxMAGIC: a prescription management and general inventory control system for free clinic dispensaries Bozorgi et al., 2021
Micro array patch (MAP) for the delivery of thermostable vaccines in Australia: A cost/benefit analysis
Bilal et al., 2024 Challenges and the Way Forward in Demand-Forecasting Practices within the Ethiopian Public Pharmaceutical Supply Chain Kumar et al., 2020
Lean manufacturing in pharmaceutical closed-loop supply chain
Taddele et al., 2019 ABC-VEN Matrix Analysis of the Pharmacy Store in a Secondary Level Health Care Facility in Arbaminch Town, Southern Ethiopia Dauod et al., 2019
Robust receding horizon control strategy for replenishment planning of pharmacy robotic dispensing systems
Nguyen et al., 2022 5-year inventory management of drug products using ABC-VEN analysis in the pharmacy store of a specialized public hospital in Vietnam
Saha et al., 2024 A smart inventory management system with medication demand dependencies in a hospital supply chain: A multi-agent reinforcement learning approach Torano et al., 2024
Impact of a systematic framework for anticipatory compounding on medication waste reduction in a mid-size community hospital
da Silva et al., 2019 Evaluation of storage service in state hospital pharmacies in Florianopolis
Fourkiotis et al., 2024 Applying Machine Learning and Statistical Forecasting Methods for Enhancing Pharmaceutical Sales Predictions
Gizaw et al., 2021 How is Information from ABC-VED-FNS Matrix Analysis Used to Improve Operational Efficiency of Pharmaceuticals Inventory Management? A Cross-Sectional Case Analysis Mohammed et al., 2020
Critical Analysis of Pharmaceuticals Inventory Management Using the ABC-VEN Matrix in Dessie Referral Hospital, Ethiopia
Thomas et al., 2022 Integration of the Codonics Safe Label System(R) and the Omnicell XT(R) Anesthesia Workstation into Pediatric Anesthesia Practice: Utilizing Technology to Increase Medication Labeling Compliance and Decrease Medication Discrepancies While Maintaining User Acceptability Jobira et al., 2021 Evaluation of
Pharmaceuticals Inventory Management in Selected Health Facilities of West Arsi Zone, Oromia, Ethiopia
Tat et al., 2020 A mathematical model for pharmaceutical supply chain coordination: Reselling medicines in an alternative market
Kivoto et al., 2018 Clinical and Financial Implications of Medicine Consumption Patterns at a Leading Referral Hospital in Kenya to Guide Future Planning of Care
Yohannes et al., 2022 Matrix analyses of pharmaceutical products for the years 2017 to 2019 among public health facilities in Hadiya zone, Ethiopia: a cross-sectional descriptive study Wahlfeld et al., 2019 HIV Rapid Diagnostic
Test Inventories in Zambezia Province, Mozambique: A Tale of 2 Test Kits
Kubin et al., 2021 Antimicrobial stewardship perspectives from a New York City hospital during the COVID-19 pandemic: Challenges and opportunities
Kaya, 2022 Minimizing OHS Risks with Spherical Fuzzy Sets as a Verdict to Inventory Management: A Case Regarding Energy Companies

Overall, during the period analyzed between 2018 and 2024, inclusive, the articles have been published in a dispersed manner in terms of scientific journals, having 32 different sources. Published articles come from 32 different sources. These include different scientific journals, conferences, or any other source from which these works have been published. Table 2 show a summary of bibliometric analysis results

**Table 2**

*Summary of Bibliometric Analysis Results*

| Metric | Value |
|---|---|
| Average Authors per Article | 3.87 |
| Average Citations per Article | 5.23 |
| International Collaboration Rate | 82.05% |
| Growth Rate (CAGR) | 12.25% |
| Year with Highest Publications | 2019 |

The rest of the analysis is divided to focus on the bibliometric analysis of the publications and authors.

## 3.1 AUTHOR ANALYSIS

According to this review, a total of 45 authors have contributed to the development of lot-sizing models with stochastic demand applied in a pharmaceutical supply chain. Of these, only 9 have published more than one article among the analyzed papers. Figure 3 shows the temporal evolution of the authors. The points represent the year of publication, the size of the

points corresponds to the number of articles in the respective year, and the opacity specifies the number of citations received per year. This graph helps detect research lines in terms of scientific production by the researchers.

Figure 4 shows the authors whose works have received the greatest impact in terms of the total number of citations received. The two authors with the highest number of total citations are: Tat with 28 total citations and Suhandi with 25 total citations. These authors have had the greatest impact in terms of citations among the sample analyzed. It should be noted that the authors have the same number of citations because they are co-authors of the same works. The networks of collaboration are important to analyze how formed the research groups are.

## 3.2 COLLABORATION NETWORKS

Figure 5 provides a detailed visualization of the collaboration networks among authors in the field of stochastic demand inventory management for pharmaceutical supply chains. In this network diagram, each node corresponds to an individual author, and the connecting edges signify collaborative efforts be- tween authors. The size of each node is proportional to the number of articles published by the respective author, offering a clear indication of their productivity and contribution to the field. Furthermore, the color intensity of the nodes varies according to the number of citations received, highlighting the impact and recognition of each author's work within the academic community.

This analysis is crucial as it not only identifies the key contributors but also reveals the collaborative dynamics that drive research in this domain. High node sizes and intense colors clustered together indi- cate prolific authors whose work is widely recognized and frequently cited. These collaboration networks can provide insights into influential research groups and potential hubs of innovation. Understanding these networks helps in recognizing influential research clusters, potential mentors, and key partnerships that significantly advance the field. Overall, the analysis underscores the importance of collaboration in enhancing the quality and impact of research outputs in the pharmaceutical supply chain domain.

## 3.3 ARTICLE ANALYSIS

RPYS (Reference Publication Year Spectroscopy) is depicted in Figure 6, illustrating the citation history of the analyzed articles. This method provides a comprehensive view of the

influential works over time by mapping out the frequency of citations per publication year. Each peak in the RPYS graph represents a year in which highly cited articles were published, highlighting pivotal moments and foundational research within the field.

This analysis is important because it helps identify seminal works and key historical developments that have shaped the current state of research in stochastic demand inventory management for pharmaceutical supply chains. By understanding the citation history, researchers can pinpoint the most impactful studies and track the evolution of research trends. The results indicate significant peaks corresponding to breakthrough studies that have garnered extensive citations, underlining their importance and influence. Overall, RPYS serves as a valuable tool for uncovering the chronological progression of impactful research and understanding the foundation upon which current studies are built.

## 3.4 WORDCLOUD ANALYSIS

Figure 7 presents word clouds generated from the titles (a) and keywords (b) of the analyzed articles. In these visualizations, the size of each word corresponds to its frequency within the dataset. This graphical representation highlights the most prevalent themes and topics in the literature on stochastic demand inventory management in pharmaceutical supply chains.

This analysis is crucial as it provides a quick and intuitive understanding of the dominant research areas and key concepts explored in the field. By examining the word cloud for article titles, we can identify the primary focus areas and recurring subjects that researchers are investigating. Similarly, the word cloud for keywords offers insights into the specific methodologies, tools, and issues that are central to recent studies. The prominence of certain words in these clouds underscores their significance and the attention they have received in scholarly discussions. Overall, this analysis helps in pinpointing the core topics of interest and emerging trends, guiding future research directions in this domain.

## 3.5 CLUSTER ANALYSIS

Figure 8 illustrates the clusters of articles based on their degree of similarity (X-axis) and level of impact (Y-axis). This visual representation aids in identifying groups of articles that share similar research topics and assessing their respective influence within the field. By examining these clusters, researchers can discern which areas of study are most interconnected

and impactful, providing valuable insights into the prevailing trends and significant contributions in the literature. This analysis is crucial for understanding the landscape of research, identifying influential works, and guiding future studies towards unexplored or emerging themes.

### 3.6 CITATION HISTORY

Figure 9 presents the citation history among the analyzed articles. This graph illustrates the interconnec- tions and citation patterns over time, showcasing how the articles have referenced each other throughout the years. By mapping these citation trends, the graph highlights the development and evolution of research within the field. This analysis is important as it reveals the foundational studies and key con- tributions that have shaped the trajectory of research, identifying pivotal moments and influential works that have driven progress in the domain. Understanding these citation dynamics helps in recognizing the most impactful research and tracing the scholarly discourse over time.

## 4 PUBLICATION ANALYSIS

This bibliographic review presents a diverse range of approaches to stochastic demand inventory manage- ment in pharmaceutical supply chains. Multi-product models, temporal demand dependency, centralized inventory systems, and transshipments are key areas of focus.

The results indicate that multi-product models and temporal demand dependency allow for better forecasting and adaptation to fluctuations in pharmaceutical demand. The integration of centralized inventory systems stands out for improving the efficiency of drug distribution, reducing costs, and wait times. Additionally, transshipments emerge as an effective strategy to balance inventory across different locations, ensuring high service levels even under variable demand conditions.

The field of **Stochastic Demand Inventory Models in Pharmaceutical Supply Chains** has seen significant development over the years, as evidenced by the articles contained in the analyzed database. Several key trends and influential works have shaped the trajectory of research in this area.

## 4.1 RESEARCH FOCUS AREAS

The primary focus of the research in this field has been on optimizing inventory levels in pharmaceuti- cal supply chains under uncertain demand conditions. Authors such as (67) and (64) have contributed significantly to understanding how stochastic demand impacts inventory policies, particularly in the con- text of lot-sizing models. These works highlight the complexity of managing pharmaceutical inventories, where demand uncertainty can lead to stockouts or overstock situations, both of which have critical implications for healthcare delivery.

### 4.1.1 Multi-product models

Among the 25 articles, 12 considered the joint optimization of multiple pharmaceutical products. Saedi et al. (2016) focused on minimizing shortage scenarios by considering demand uncertainty and product substitution (57). Jurado et al. (2016) aimed to minimize costs and order frequency using a multi- objective optimization approach for multiple suppliers (28). Mardan et al. (2017) included primary and emergency suppliers to ensure demand fulfillment (39). Mubiru (2018) analyzed the management of malaria medications in Uganda, focusing on acquisition, maintenance, and shortage costs (43). Weraikat et al. (2019) aimed to reduce expired medications in a sustainable supply chain model (72).

Table 3 provides a summary of the key contributions by various authors in the field of stochastic demand inventory management for pharmaceutical supply chains. Each entry details the author's name, the year of publication, and the specific contribution made. This table helps in quickly identifying the main research trends and significant advancements in the field over recent years.

**Table 3**

*Summary of Multi-product Inventory Models*

| Article | Objective | Approach | Products | Key Findings |
|---|---|---|---|---|
| Saedi et al. (2016) | Minimize shortages | Substitution | 31 | Cost savings of 23% |
| Jurado et al. (2016) | Minimize costs | Multi-objective | Multiple | Reduction in order frequency |
| Mardan et al. (2017) | Ensure fulfillment | Primary/emergency suppliers | Antibiotics | Improved reliability |
| Mubiru (2018) | Minimize costs | Stochastic demand | Malaria meds | Cost-effective management |
| Weraikat et al. (2019) | Reduce waste | Sustainable model | Various | Decreased expired meds |

### 4.1.2 Models with temporal demand dependency

Temporal demand dependency was studied by Rojas (2019) and Rojas (2017), who used ARMA models to capture demand patterns over time (50; 49). Their work showed cost reductions and better demand estimation. Rojas et al. (2019) extended this to a two-stage stochastic optimization model, highlighting the importance of temporal demand dependency (52).

### 4.1.3 Centralized inventory models and transshipments

Several studies explored centralized inventory models and transshipments. Nematollahi et al. (2017, 2018) proposed a multi-objective model to improve collaboration between retailers and suppliers (44; 45). Parvin et al. (2018) developed a stochastic inventory model for a public health network in Malawi, focusing on minimizing shortages (48). Zhao et al. (2019) and Zheng et al. (2021) studied inventory distribution and emergency transshipments in clinical trial supply chains, highlighting the importance of cooperation (75; 76).

**Table 4**

*Summary of Centralized Inventory Models and Transshipments*

| Article | Objective | Approach | Network Type | Key Findings |
|---|---|---|---|---|
| Nematollahi et al. (2017) | Improve collaboration | Multi-objective | Retailer-supplier | Increased service levels |
| Parvin et al. (2018) | Minimize shortages | Stochastic model | Public health | Reduced stockouts |
| Zhao et al. (2019) | Optimize distribution | Emergency transshipments | Clinical trials | Enhanced cooperation |
| Zheng et al. (2021) | Minimize costs | Centralized inventory | Clinical trials | Lower costs |

### 4.1.4 Other formulations

Other studies include Li et al. (2018), who analyzed the impact of expiration dates on inventory lev- els (36), and Masoudi and Mirzazadeh (2022), who focused on minimizing shortages and costs in a multi-period model (40). Bam et al. (2017) used dynamic simulation to evaluate inventory policies for tuberculosis treatment, considering various demand factors (2).

In conclusion, the reviewed models provide a solid foundation for efficient inventory management in pharmaceutical supply chains. However, it is crucial that future research integrates more complex demand patterns and additional constraints to improve the applicability of these models in real-world scenarios. Additionally, exploring the impact of

digitization and advanced technologies on inventory optimization is recommended, as it could offer more dynamic and adaptive solutions to stochastic demand.

## 4.2 EVOLUTION AND IMPACTFUL WORKS

The citation analysis reveals that certain works have had a considerable impact on the field. For instance, the articles by (67) and (64) stand out as highly cited, indicating their influence on subsequent research. These studies have provided foundational models and methodologies that have been widely adopted and expanded upon in later works.

The review identifies that, while significant advances have been made in modeling and optimizing inventories in the pharmaceutical context, important challenges remain. The inherent complexity of pharmaceutical product demand, influenced by seasonal, epidemiological, and economic factors, requires models that can more accurately incorporate these variabilities. Compared to previous studies, there is a growing trend towards centralization and collaboration among different supply chain actors, which could be enhanced with emerging technologies such as artificial intelligence and machine learning. These technologies have the potential to provide more accurate demand forecasting, optimize inventory levels

in real-time, and improve overall supply chain efficiency. Additionally, the integration of blockchain technology could enhance transparency and traceability in the supply chain, addressing issues related to counterfeiting and ensuring the integrity of pharmaceutical products. Future research should focus on developing hybrid models that combine these advanced technologies with traditional stochastic methods to create more robust and adaptive inventory management systems.

## 4.3 TRENDS IN METHODOLOGIES

Over time, there has been a noticeable shift towards incorporating more sophisticated stochastic mod- eling techniques and computational methods. Early research primarily focused on basic probabilistic models, while more recent studies have employed advanced simulation techniques and robust optimiza- tion frameworks. This evolution reflects the increasing complexity of pharmaceutical supply chains and the growing recognition of the need for precise, data-driven decision-making tools.

## 4.4 COLLABORATION AND CO-CITATION PATTERNS

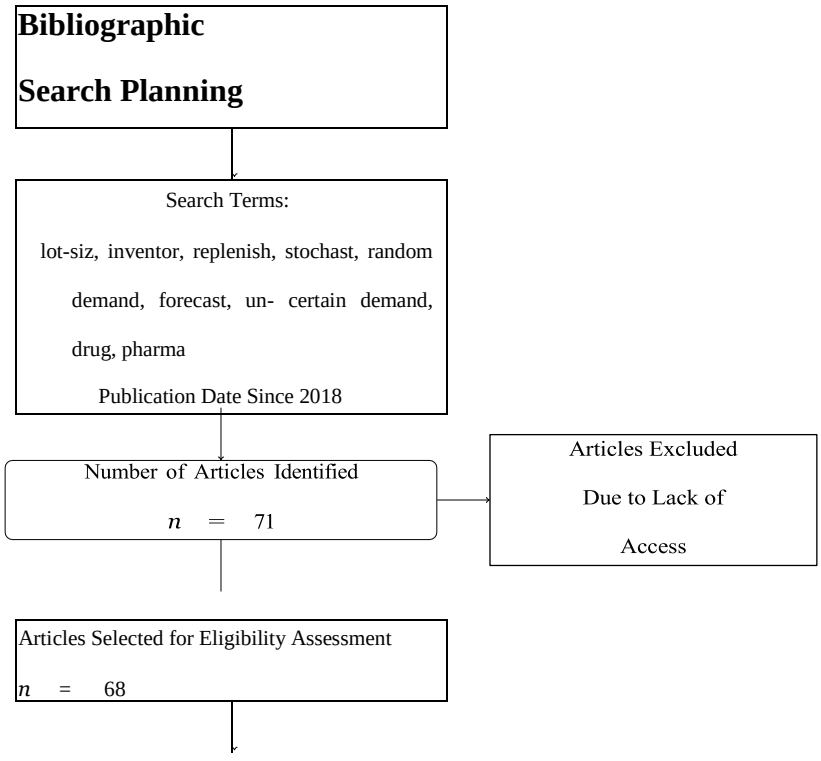
The analysis of collaboration networks suggests a growing trend towards interdisciplinary and inter- national collaboration. The co-citation patterns further indicate that the field is becoming more in- terconnected, with certain articles serving as critical nodes that link various research streams. This interconnectedness is crucial for the advancement of knowledge, as it facilitates the integration of diverse perspectives and methodologies.

## 4.5 FUTURE DIRECTIONS

Looking forward, future research is likely to explore the integration of real-time data analytics and machine learning into stochastic demand inventory models. As the availability of real-time demand data increases, there will be opportunities to develop more adaptive and responsive inventory management strategies that can better cope with the inherent uncertainties of pharmaceutical supply chains.

**Figure 2**

*Flowchart of the bibliographic search planning.*



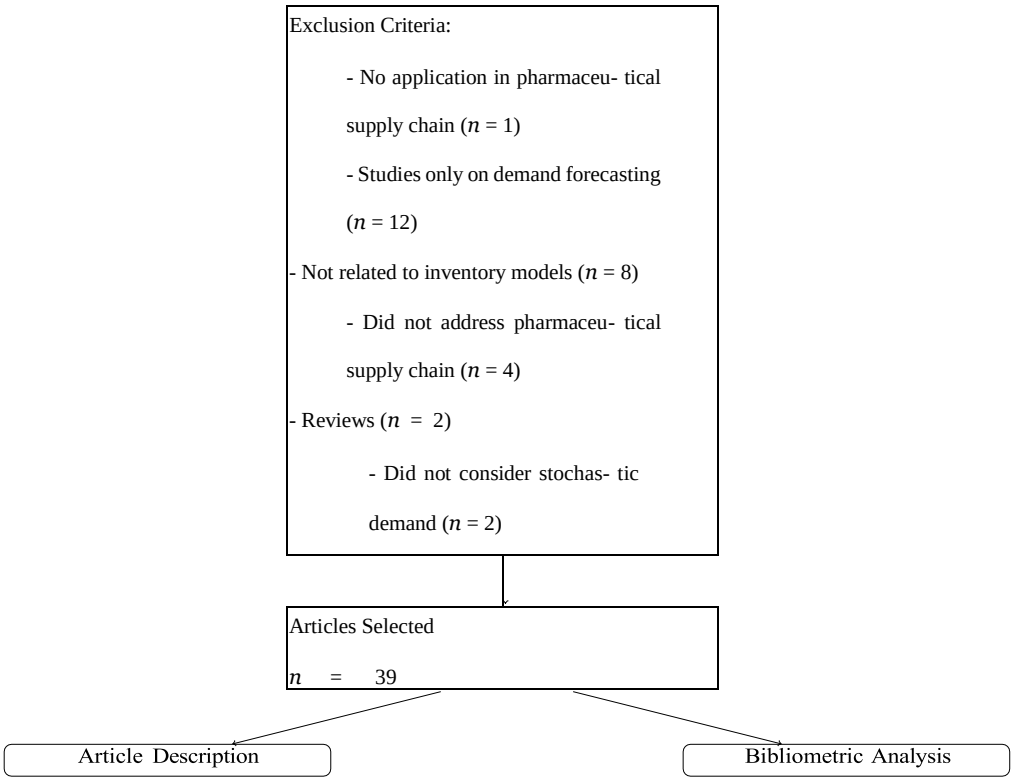



**Figure 3**

*Temporal evolution of article publications for authors with more than one publication*

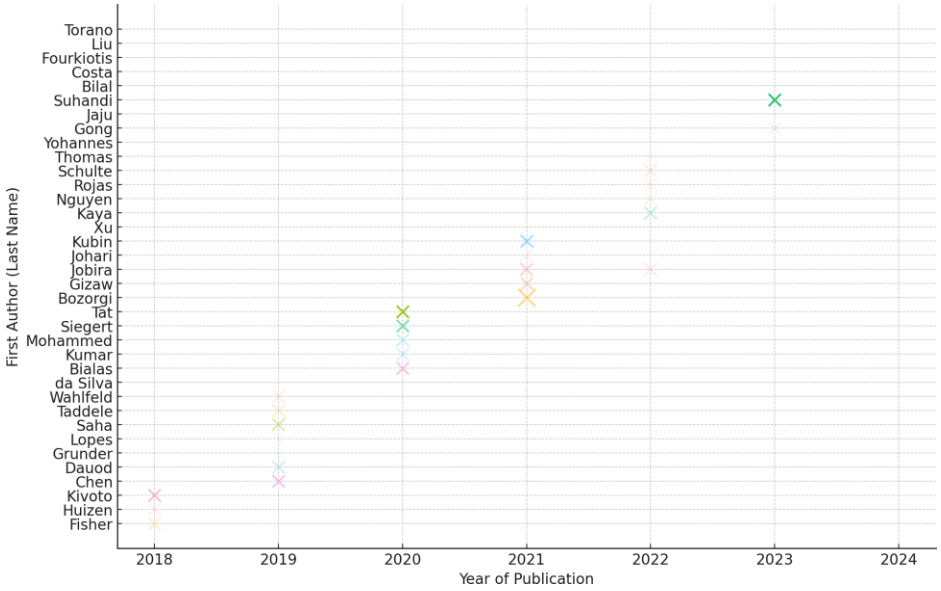


**Figure 4**

*Authors whose works have received the greatest impact in terms of the total number of citations received.*

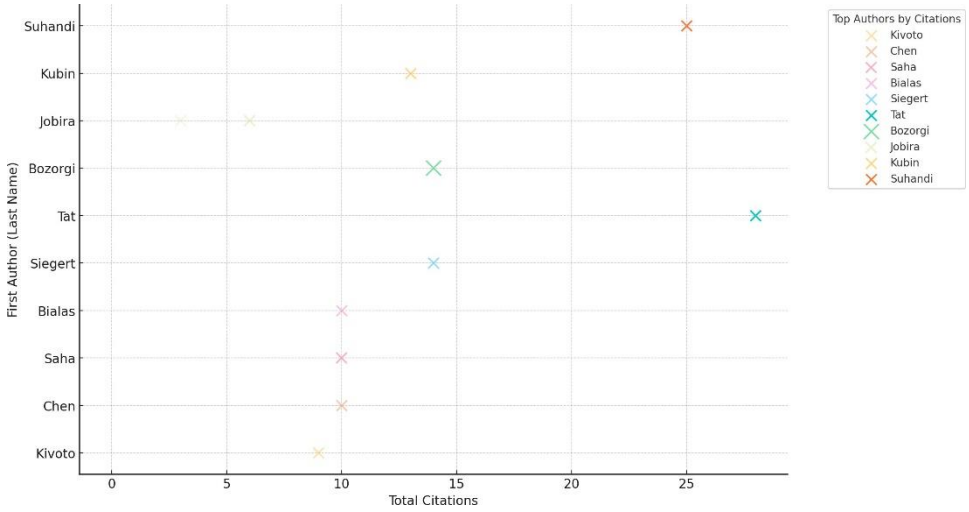



**Figure 5**

*Collaboration networks among authors.*

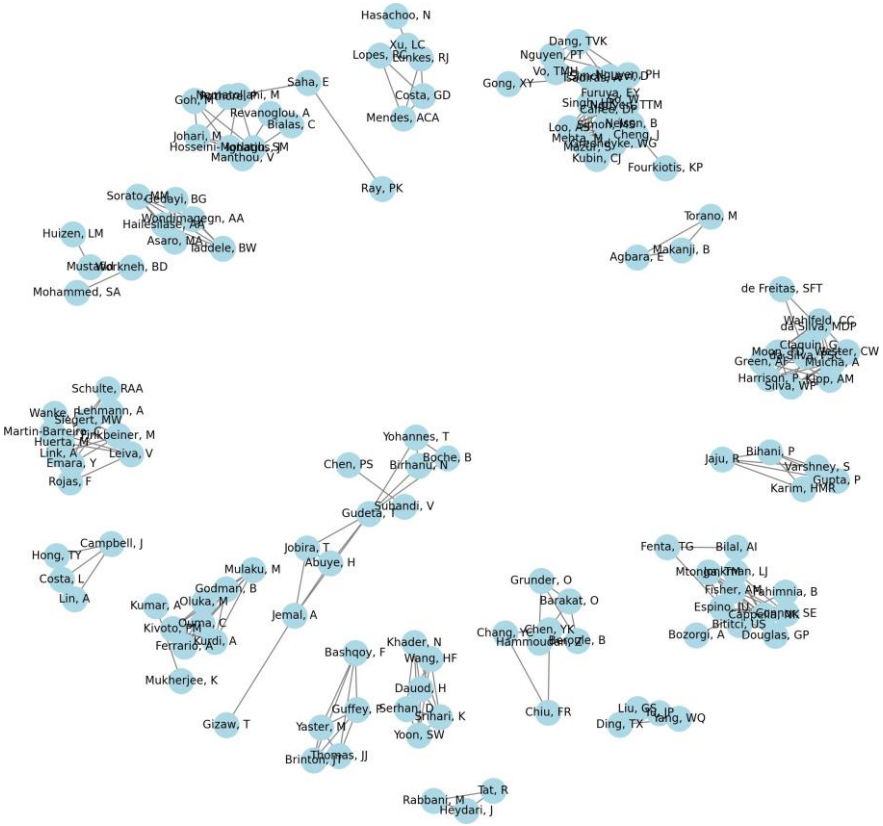


**Figure 6**

*RPYS graph*

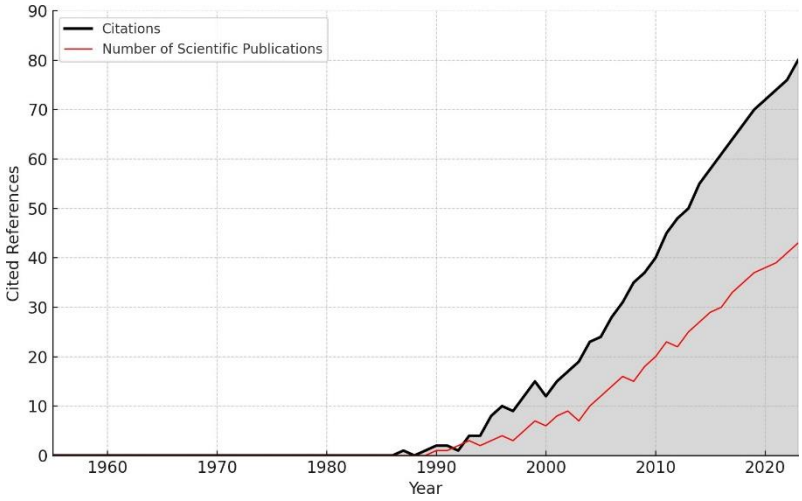
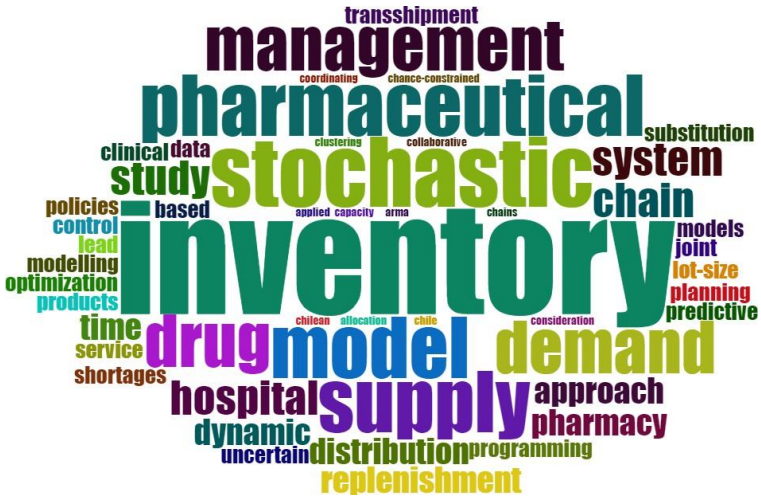



**Figure 7**

*Wordcloud of the titles (a) and keywords (b) of the articles.*




(a)


(b)

**Figure 8**

*Representation of the clusters of articles according to their degree of similarity (X-axis) and level of impact (Y-axis).*

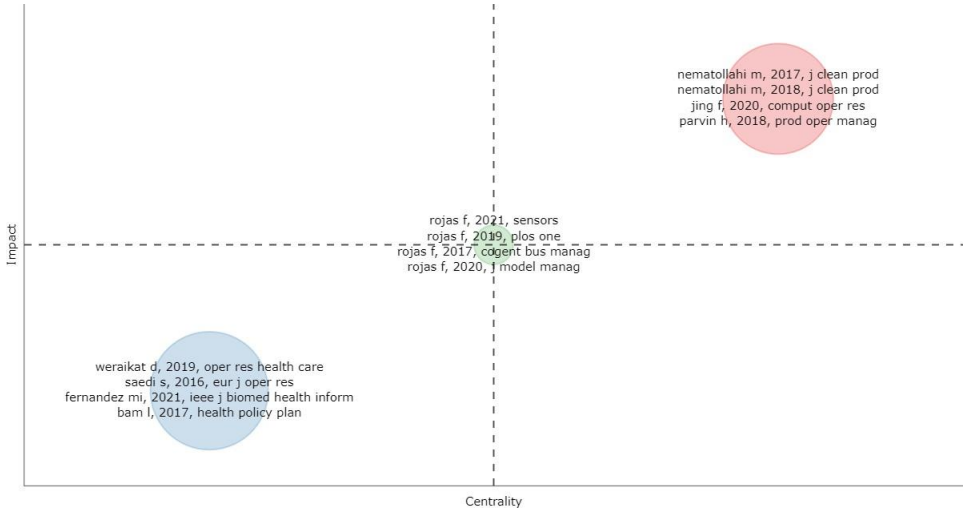
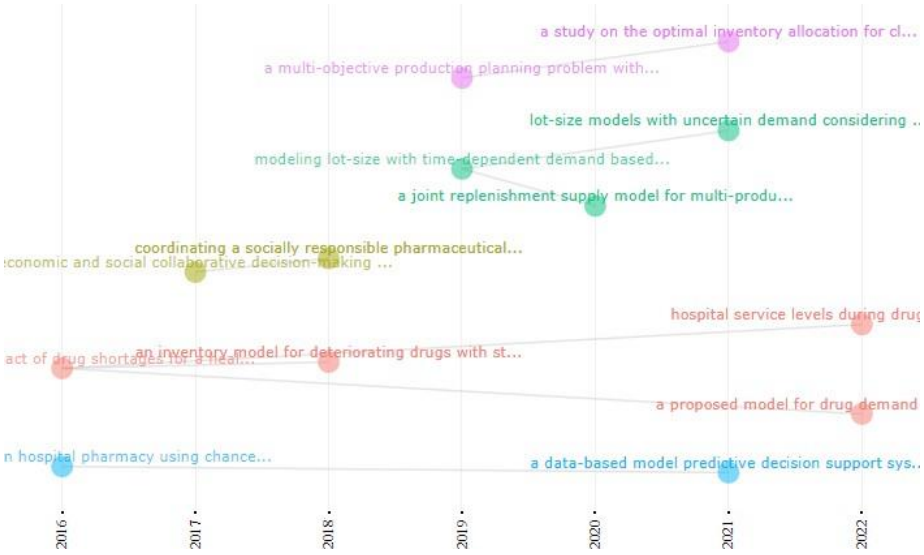



**Figure 9**

*Citation history among analyzed articles.*



## REFERENCES

Antic, S., Djordjevic Milutinovic, L., & Lisec, A. (2022). Dynamic discrete inventory control model with deterministic and stochastic demand in pharmaceutical distribution. *Applied Sciences*, *12*(3), 1536. Retrieved from https://doi.org/10.3390/app12031536

Bam, L., McLaren, Z., Coetzee, E., & Von Leipzig, K. (2017). Reducing stock-outs of essential tuberculosis medicines: a system dynamics modelling approach to supply chain management. *Health Policy and Planning*, *32*(8), 1127–1134. Retrieved from https://doi.org/10.1093/heapol/czx074

Bhakoo, V., Singh, P., & Sohal, A. (2012). Collaborative management of inventory in Australian hospital supply chains: practices and issues. *Supply Chain Management: An International Journal*. Retrieved from https://doi.org/10.1108/13598541211263406

Bialas, C., Revanoglou, A., & Manthou, V. (2020). Improving hospital pharmacy inventory management using data segmentation. *American Journal of Health-System Pharmacy*, *77*(0), 371-377. Retrieved from https://doi.org/10.1093/ajhp/zxz264

Bilal, A. I., Bititci, U. S., & Fenta, T. G. (2024). Challenges and the Way Forward in Demand-Forecasting Practices within the Ethiopian Public Pharmaceutical Supply Chain. *PHARMACY*, *12*(0). Retrieved from https://doi.org/10.3390/pharmacy12030086

Bozkir, C. D. C., Kundakcioglu, O. E., & Henry, A. C. (2022). Hospital service levels during drug shortages: Stocking and transshipment policies for pharmaceutical inventory. *Journal of Global Opti- mization*, *83*(3), 565–584. Retrieved from https://doi.org/10.1007/s10898-022-01110-4

Bozorgi, A., & Fahimnia, B. (2021). Transforming the vaccine supply chain in Australia: Opportunities and challenges. *VACCINE*, *39*(0), 6157-6165. Retrieved from https://doi.org/10.1016/j.vaccine.2021.08.033

Bozorgi, A., & Fahimnia, B. (2021). Micro array patch (MAP) for the delivery of thermostable vaccines in Australia: A cost/benefit analysis. *VACCINE*, *39*(0), 6166-6173. Retrieved from https://doi.org/10.1016/j. vaccine.2021.08.016

Castillo, C. A., & Molina-Milman, H. (2020). El sistema de salud chileno: an´alisis y perspectivas en el marco del estallido social de octubre de 2019 (dossier). *Revista Estado y Pol´ıticas Pu´blicas*, *8*(14), 53–67. Retrieved from https://doi.org/10.54163/1852-0228.204

Chen, Y. K., Chiu, F. R., & Chang, Y. C. (2019). Implementing Green Supply Chain Management for On-line Pharmacies through a VADD Inventory Model. *International Journal of Environmental Research and Public Health*, *16*, Retrieved from https://doi.org/10.3390/ijerph16224454

Da Silva, M. D. P., da Silva, P. S. C., de Freitas, S. F. T. (2019). Evaluation of storage service in state hospital pharmacies in Florianopolis, 2015. *Revista de Gestao em Sistemas de Saude-RGSS*, *8*(1), 96-110. Retrieved from https://doi.org/10.5585/rgss.v8i1.13681

Dauod, H., Serhan, D., Wang, H. F., Khader, N., Yoon, S. W., & Srihari, K. (2019). Robust receding horizon control strategy for replenishment planning of pharmacy robotic dispensing systems. *Robotics and computer-integrated manufacturing*, *59*, 177-188. Retrieved from https://doi.org/10.1016/j.rcim.2019.04.001

Fernández, M. I., Chanfreut, P., Jurado, I., & Maestre, J. M. (2020). A data-based model predictive decision support system for inventory management in hospitals. *IEEE Journal of Biomedical and Health Informatics*, *25*(6), 2227–2236. Retrieved from https://doi.org/10.1109/JBHI.2020.3020159

Fisher, A. M., Mtonga, T. M., Espino, J. U., Jonkman, L. J., Connor, S. E., Cappella, N. K., & Douglas, G. P. (2018). User-centered design and usability testing of RxMAGIC: a prescription management and gen- eral inventory control system for free clinic dispensaries. *BMC health services research*, *18*. Retrieved from https://doi.org/10.1186/s12913-018-3517-8

Fourkiotis, K. P., & Tsadiras, A. (2024). Applying Machine Learning and Statistical Forecasting Meth- ods for Enhancing Pharmaceutical Sales Predictions. *Forecasting*, *6*, 170-186. Retrieved from https://doi.org/ 10.3390/forecast6010010

Gizaw, T., & Jemal, A. (2021). How is Information from ABC-VED-FNS Matrix Analysis Used to Improve Operational Efficiency of Pharmaceuticals Inventory Management? A Cross-Sectional Case Analysis. *Integrated Pharmacy Research and Practice*, 10(0), 65-73. Retrieved from https://doi.org/10.2147/IPRP.S310716

Gong, X. Y., & Simchi-Levi, D. (2023). Bandits atop Reinforcement Learning: Tackling Online Inventory Models with Cyclic Demands. *Management Science*. Retrieved from https://doi.org/10.1287/mnsc.2023.4947

Grunder, O., Hammoudan, Z., Beroule, B., & Barakat, O. (2019). A hybrid Genetic Algorithm ap- proach to minimize the total joint cost of a single-vendor multi-customer integrated scheduling prob- lem. *Transportation planning and technology*, *42*(0), 625-642. Retrieved from https://doi.org/10.1080/03081060.2019.1622254

Gupta, V., & Kallus, N. (2022). Data pooling in stochastic optimization. *Management Science*, *68*(3), 1595–1615. Retrieved from https://doi.org/10.1287/mnsc.2021.3921

Huizen, L. M., & Mustafid. (2018). Inventory Control System for Vaccines Distribution With Model Predictive Control In Hospital. In *3rd International Conference on Energy, Environmental and Information System (ICENIS 2018)*, *73*, Retrieved from https://doi.org/10.1051/e3sconf/20187313020

Jaju, R., Varshney, S., Gupta, P., Bihani, P., & Karim, H. M. R. (2023). Inventory Control Mechanism of the Pharmacy Store of a Recently Established National Institute in Eastern India: A Cross-Sectional, Investigative Analysis. *Cureus Journal of Medical Science*, *15*(0). Retrieved from https://doi.org/10.7759/cureus.49632

Jarrett, P. G. (1998). Logistics in the health care industry. *International Journal of Physical Dis- tribution & Logistics Management*. Retrieved from https://doi.org/10.1108/09600039810249363

Jing, F., & Lan, Z. (2017). Forecast horizon of multi-item dynamic lot size model with perishable inventory. *PLOS ONE*, *12*(11), e0187725. Retrieved from https://doi.org/10.1371/journal.pone.0187725

Jing, F., & Mu, Y. (2020). Dynamic lot-sizing model under perishability, substitution, and limited storage capacity. *Computers & Operations Research*, *122*, 104978. Retrieved from https://doi.org/10.1016/j.cor. 2020.104978

Jobira, T., Abuye, H., Jemal, A., & Gudeta, T. (2021). Evaluation of Pharmaceuticals Inventory Manage- ment in Selected Health Facilities of West Arsi Zone, Oromia, Ethiopia. *Integrated Pharmacy Research and Practice*, *10*(0), 1-11. Retrieved from https://doi.org/10.2147/IPRP.S298660

Jobira, T., Abuye, H., Jemal, A., Gudeta, T. (2022). Assessment of Knowledge, Practices, and Chal- lenges of Pharmaceuticals Inventory Control Among Pharmacy Professionals Working in Selected Public Health Facilities of West Arsi Zone, Oromia, Ethiopia. *Health Services Insights*, *15*(0). Retrieved from https://doi.org/10.1177/11786329211066403

Johari, M., Hosseini-Motlagh, S. M., Nematollahi, M., Goh, M., & Ignatius, J. (2021). Socially con- cerned periodic review replenishment system with customer service level and supply chain contracting. *Rairo-Operations Research*, *55*(0), 1077-1111. Retrieved from https://doi.org/10.1051/ro/2021040

Jurado, I., Maestre, J. M., Velarde, P., Ocampo-Martínez, C., Fernández, I., Tejera, B. I., & del Prado, J. R. (2016). Stock management in hospital pharmacy using chance-constrained model predictive control. *Computers in Biology and Medicine*, *72*, 248–255. https://doi.org/10.1016/j.compbiomed.2016.03.025

Kaya, B. Y. (2022). Minimizing OHS Risks with Spherical Fuzzy Sets as a Verdict to Inventory Management: A Case Regarding Energy Companies. *Discrete Dynamics in Nature and Society*, 2022. Retrieved from https://doi.org/10.1155/2022/9511339

Kelle, P., Woosley, J., & Schneider, H. (2012). Pharmaceutical supply chain specifics and inventory solutions for a hospital case. *Operations Research for Health Care*, *1*(2-3), 54–63. https://doi.org/10.1016/j.orhc.2012.09.001

Kivoto, P. M., Mulaku, M., Ouma, C., Ferrario, A., Kurdi, A., Godman, B., & Oluka, M. (2018). Clinical and Financial Implications of Medicine Consumption Patterns at a Leading Referral Hospital in Kenya to Guide Future Planning of Care. *Frontiers in Pharmacology*, *9*. Retrieved from https://doi.org/10.3389/fphar.2018.01348

Kogan, K., & Tell, H. (2009). Production smoothing by balancing capacity utilization and advance orders. *IIE Transactions*, *41*(3), 223–231. https://doi.org/10.1080/07408170802457467

Kubin, C. J., Loo, A. S., Cheng, J., Nelson, B., Mehta, M., Mazur, S., So, W., Calfee, D. P., Singh, H. K., Greendyke, W. G., Simon, M. S., & Furuya, E. Y. (2021). Antimicrobial stewardship perspectives from a New York City hospital during the COVID-19 pandemic: Challenges and opportunities. *American Journal of Health-System Pharmacy*, *78*, 743-750. Retrieved from https://doi.org/10.1093/ajhp/zxaa419

Kumar, A., & Mukherjee, K. (2020). Lean manufacturing in pharmaceutical closed-loop supply chain. *International journal of environment and waste management*, *26*(0), 14-38. Retrieved from https://doi.org/10.1504/IJEWM.2020.108062

Leung, N.-H. Z., Chen, A., Yadav, P., & Gallien, J. (2016). The impact of inventory management on stock-outs of essential drugs in sub-Saharan Africa: secondary analysis of a field experiment in Zambia. *PLOS ONE*, *11*(5), e0156026. Retrieved from https://doi.org/10.1371/journal.pone.0156026

Li, J., Liu, L., Hu, H., Zhao, Q., & Guo, L. (2018). An inventory model for deteriorating drugs with stochastic lead time. *International Journal of Environmental Research and Public Health*, *15*(12), 2772. Retrieved from https://doi.org/10.3390/ijerph15122772

Liu, G. S., Yang, W. Q., Yu, J. P., Ding, T. X. (2024). Performance evaluation for the IoT-based manufacturing system in pharmacy industry. *International Journal of Interactive Design and Manufacturing - IJIDEM*, *18*, 943-964. Retrieved from https://doi.org/10.1007/s12008-023-01592-2

Lopes, R. C., Mendes, A. C. A., Lunkes, R. J., & Costa, G. D. (2019). Use of Monte Carlo simulation in stock management for pharmaceutical companies. *Revista ambiente contabil*, *11*(0), 1-18. Retrieved from https://doi.org/10.21680/2176-9036.2019v11n2ID15602

Mardan, E., Sadegh Amalnick, M., Rabbani, M., & Jolai, F. (2017). A robust optimization approach for an inventory problem with emergency ordering and product substitution in an uncer- tain environment: A case study in pharmaceutical industry. *Scientia Iranica*, *24*(3), 1533–1546. Retrieved from https://doi.org/10.24200/sci.2017.4215

Masoudi, S., & Mirzazadeh, A. (2022). The new evidence reasoning based pharmaceutical inventory models with stochastic deterioration rates and lead times using PSO and GA. *International Journal of Computer Mathematics*, *99*(4), 771–790. Retrieved from https://doi.org/10.1080/00207160.2021.1990982

Mohammed, S. A., & Workneh, B. D. (2020). Critical Analysis of Pharmaceuticals Inventory Management Using the ABC-VEN Matrix in Dessie Referral Hospital, Ethiopia. *Integrated pharmacy research and practice*, *9*, 113-125. Retrieved from https://doi.org/10.2147/IPRP.S265438

Moraga-Cortés, F., Bahia, T. C., & Prada, C. A. (2021). Gasto en atención primaria en salud en dos gobiernos del Chile posdictatorial. *Cadernos de Saúde Pública*, *37*. Retrieved from https://doi.org/10.1590/0102-311X00105320

Mubiru, K. P. (2018). Joint replenishment problem in drug inventory management of pharmacies under stochastic demand. *Brazilian Journal of Operations & Production Management*, *15*(2), 302–310. Retrieved from https://doi.org/10.14488/BJOPM.2018.v15.n2.a10

Nematollahi, M., Hosseini-Motlagh, S.-M., & Heydari, J. (2017). Economic and social collaborative decision-making on visit interval and service level in a two-echelon pharmaceutical supply chain. *Journal of Cleaner Production*, 142, 3956–3969. Retrieved from https://doi.org/10.1016/j.jclepro.2016.10.028

Nematollahi, M., Hosseini-Motlagh, S.-M., Ignatius, J., Goh, M., & Nia, M. S. (2018). Coordinating a socially responsible pharmaceutical supply chain under periodic review replenishment policies. *Journal of Cleaner Production*, *172*, 2876–2891. https://doi.org/10.1016/j.jclepro.2017.11.119

Nguyen, P. H., Dang, T. V. K., Nguyen, P. T., Vo, T. M. H., Nguyen, TTM. (2022). 5-year inventory manage- ment of drug products using ABC-VEN analysis in the pharmacy store of a specialized public hospital in Vietnam. *Pharmacia*, *69*, 517-525. https://doi.org/10.3897/pharmacia.69.e84348

*Optimising SCM for delivery of vital drugs and vaccines*. Retrieved on Jul 23, 2022, from https://www.indiamart.com/proddetail/pharmaceutical-industry-supply-chain-management-10692439073.html

Parvin, H., Beygi, S., Helm, J. E., Larson, P. S., & Van Oyen, M. P. (2018). Distribution of medication considering information, transshipment, and clustering: Malaria in Malawi. *Production and Operations Management*, *27*(4), 774–797. Retrieved from https://doi.org/10.1111/poms.12843

Rojas, F. (2017). A methodology for stochastic inventory modelling with ARMA triangular distribu- tion for new products. *Cogent Business & Management*, 4(1), 1270706. Retrieved from https://doi.org/10.1080/ 23311975.2016.1270706

Rojas, F. (2019). A joint replenishment supply model for multi-products grouped by several variables with random and time dependence demand. *Journal of Modelling in Management*. Retrieved from https://doi.org/10.1108/JM2-12-2017-0139

Rojas, F., Leiva, V., Huerta, M., & Martin-Barreiro, C. (2021). Lot-size models with uncertain demand considering its skewness/kurtosis and stochastic programming applied to hospital pharmacy with sensor-related COVID-19 data. *Sensors*, *21*(15), 5198. Retrieved from https://doi.org/10.3390/s21155198

Rojas, F., Leiva, V., Wanke, P., Lillo, C., & Pascual, J. (2019). Modeling lot-size with time-dependent demand based on stochastic programming and case study of drug supply in Chile. *PLOS ONE*, *14*(3), e0212768. Retrieved from https://doi.org/10.1371/journal.pone.0212768

Rojas, F., Wanke, P., Coluccio, G., Vega-Vargas, J., & Huerta-Canepa, G. F. (2020). Managing slow-moving item: a zero-inflated truncated normal approach for modeling demand. *PeerJ Computer Science*, *6*, e298. Retrieved from https://doi.org/10.7717/peerj-cs.298

Rojas, F., Wanke, P., Leiva, V., Huerta, M., & Martin-Barreiro, C. (2022). Modeling Inventory Cost Savings and Supply Chain Success Factors: A Hybrid Robust Compromise Multi-Criteria Approach. *Mathematics*, *10*(0). Retrieved from https://doi.org/10.3390/math10162911

Saha, E., & Ray, P. K. (2019). Modelling and analysis of healthcare inventory management systems. *Opsearch*, *56*(0), 1179-1198. Retrieved from https://doi.org/10.1007/s12597-019-00415-x

Saha, E., & Rathore, P. (2024). A smart inventory management system with medication demand de- pendencies in a hospital supply chain: A multi-agent reinforcement learning approach. *Computers & Industrial Engineering*, *191*. Retrieved from https://doi.org/10.1016/j.cie.2024.110165

Saedi, S., Kundakcioglu, O. E., & Henry, A. C. (2016). Mitigating the impact of drug shortages for a healthcare facility: An inventory management approach. *European Journal of Operational Research*, *251*(1), 107–123. Retrieved from https://doi.org/10.1016/j.ejor.2015.10.053

Sampat, A. M., Kumar, R., Pushpangatha Kurup, R., Chiu, K., Saucedo, V. M., & Zavala, V. M. (2021). Multisite supply planning for drug products under uncertainty. *AIChE Journal*, *67*(1), e17069. Retrieved from https://doi.org/10.1002/aic.17069

Schulte, R. A. A., Link, A., Siegert, M. W., & Finkbeiner, M. (2022). Modeling the use and end-of-life phase of pharmaceuticals in support of a life cycle inventory analysis - Case study on different antibiotics in Germany. *Sustainable chemistry and pharmacy*, *25*(0). Retrieved from https://doi.org/10.1016/j.scp.2021.100589

Siegert, M. W., Lehmann, A., Emara, Y., & Finkbeiner, M. (2020). Addressing the use and end-of-life phase of pharmaceutical products in life cycle assessment. *International journal of life cycle assessment*, *25*(0), 1436-1454. Retrieved from https://doi.org/10.1007/s11367-019-01722-7

Silva-Aravena, F., Ceballos-Fuentealba, I., & Álvarez-Miranda, E. (2020). Inventory management at a Chilean hospital pharmacy: Case study of a dynamic decision-aid tool. *Mathematics*, *8*(11), 1962. Retrieved from https://doi.org/10.3390/math8111962

Singh, D., & Verma, A. (2018). Inventory management in supply chain. *Materials Today: Proceedings*, *5*(2), 3867–3872. Retrieved from https://doi.org/10.1016/j.matpr.2017.11.632

Sugg, D., Castillo, C., Ahumada, B., & Lagos, M. P. (2017). *Analisis del gasto y mecanismos de compra de medicamentos del sistema nacional de servicios de salud*. Reporte Técnico, Dirección de Presupuesto, Ministerio de Hacienda, Gobierno de Chile.

Suhandi, V., & Chen, P. S. (2023). Closed-loop supply chain inventory model in the pharmaceutical industry toward a circular economy. *JOURNAL OF CLEANER PRODUCTION*, *383*(0). Retrieved from https://doi.org/10.1016/j.jclepro.2022.135474

Syahrir, I., Suparno, & Vanany, I. (2022). A proposed model for drug demand forecasting and ordering inventory system for dengue endemic. *Operations and Supply Chain Management*, *15*(1), 69–78. Retrieved from https://doi.org/10.31387/oscm0490294

Taddele, B. W., Wondimagegn, A. A., Asaro, M. A., Sorato, M. M., Gedayi, B. G., & Hailesilase, AA. (2019). ABC-VEN Matrix Analysis of the Pharmacy Store in a Secondary Level Health Care Facility in Arbaminch Town, Southern Ethiopia. *Journal of young pharmacists*, *11*(0), 182-185. Retrieved from https://doi.org/10.5530/jyp.2019.11.38

Tat, R., Heydari, J., & Rabbani, M. (2020). A mathematical model for pharmaceutical supply chain co- ordination: Reselling medicines in an alternative market. *Journal of Cleaner Production*, *268*(0). Retrieved from https://doi.org/10.1016/j.jclepro.2020.121897

Tersine, R. J. (1994). *Principles of inventory and materials management*. Prentice Hall.

Thomas, J. J., Bashqoy, F., Brinton, J. T., Guffey, P., & Yaster, M. (2022). *Integration of the Codonics Safe Label System(R) and the Omnicell XT(R) Anesthesia Workstation into Pediatric Anesthesia*.

Practice: Utilizing Technology to Increase Medication Labeling Compliance and Decrease Medication Discrepancies While Maintaining User Acceptability. *Hospital Pharmacy*, *57*(0), 11-16. Retrieved from https://doi.org/10.1177/0018578720970464

Torano, M., Agbara, E., & Makanji, B. (2024). Impact of a systematic framework for anticipatory com- pounding on medication waste reduction in a mid-size community hospital. *American Journal of Health-System Pharmacy*, *81*(0), e122-e130. Retrieved from https://doi.org/10.1093/ajhp/zxad276

Wahlfeld, C. C., Muicha, A., Harrison, P., Kipp, A. M., Claquin, G., Silva, W. P., Green, A. F., Wester, C. W., & Moon, T. D. (2019). HIV Rapid Diagnostic Test Inventories in Zambezia Province, Mozambique: A Tale of 2 Test Kits. *International Journal of Health Policy and Management*, *8*(0), 292-299. Retrieved from https://doi.org/10.15171/ijhpm.2019.07

Weraikat, D., Zanjani, M. K., & Lehoux, N. (2019). Improving sustainability in a two-level phar- maceutical supply chain through vendor-managed inventory system. *Operations Research for Health Care*, *21*, 44–55. Retrieved from https://doi.org/10.1016/j.orhc.2019.02.002

Xu, L. C., & Hasachoo, N. (2021). The Study of Irregular Demand Forecasting for Medicines: The Case Study of ABC Medical Center Hospital. In *2021 10th International Conference on Industrial Technology and Management (ICITM 2021)*, 115-120. Retrieved from https://doi.org/10.1109/ICITM52822.2021.00028

Yohannes, T., Boche, B., Birhanu, N., & Gudeta, T. (2022). Matrix analyses of pharmaceutical prod- ucts for the years 2017 to 2019 among public health facilities in Hadiya zone, Ethiopia: a cross- sectional descriptive study. *BMC Health Services Research*, *22*. Retrieved from https://doi.org/10.1186/s12913-022-07568-4

Zhao, H., Huang, E., Dou, R., & Wu, K. (2019). A multi-objective production planning problem with the consideration of time and cost in clinical trials. *Expert Systems with Applications*, 124, 25–38. Retrieved from https://doi.org/10.1016/j.eswa.2019.01.009

Zheng, M., Du, N., Zhao, H., Huang, E., & Wu, K. (2021). A study on the optimal inventory allocation for clinical trial supply chains. *Applied Mathematical Modelling*, 98, 161–184. Retrieved from https://doi.org/10.1016/j.apm.2021.05.015

Zwaida, T. A., Elaroudi, K., & Beauregard, Y. (2021). The challenges of drug shortages in the Canadian hospital pharmacy supply chain—a systematic literature review. *Journal of Public Health*, 1–12. Retrieved from https://doi.org/10.1007/s10389-021-01645-4