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Toward a Demand-Driven Supply Chain: BLR Evaluating the Impact of AI and ML Integration in the Healthcare and Pharmaceutical Industry †

Majda Boualam * and Imane Ibn El Farouk

Laboratory for Studies and Research in Economics and Management Sciences (LERSEM), National School of Business and Management (ENCG), University Chouaïb Doukkali (UCD), El Jadida 24010, Morocco; ibnelfarouk.i@ucd.ac.ma

* Correspondence: boualam.majda@ucd.ac.ma

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Abstract: The application of Artificial Intelligence and Machine Learning in the supply chain fields is significantly changing the way businesses manage their operations, forecast their demand, manage their inventory, optimize their logistics, and increase their level of resilience. This research explores, through a bibliometric literature review, how the integration of these technologies can support the implementation of a demand-driven supply chain approach in the global healthcare and pharmaceutical supply chains, which are facing remarkable challenges in ensuring demand-driven operations, especially in light of sudden disruptions such as the COVID-19 pandemic.

Keywords: Demand-Driven Supply Chain (DDSC); Artificial Intelligence (AI); Machine Learning (ML); pharma industry; healthcare; Bibliometric Literature Review (BLR)

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1. Introduction

The adoption of a demand-driven approach has been essential for supply chains with the aim of optimizing their utilization of resources, reducing waste, and better managing inventories by generating more accurate demand forecasting that is mainly based on real-time data [1]. The application of DDSC practices has been growing in multiple sectors. Being driven primarily by real-time visibility into both demand and supply data, DDSC has significantly improved supply chain efficiency and has enabled effective demand planning [2].

The implementation of technologies related to AI and ML into supply chain and demand forecasting is important as it allows businesses to respond more quickly to market fluctuations and maintain their competitive margin [3].

Healthcare and pharmaceutical supply chains usually face fluctuations, disruptions, and inefficiencies in demand forecasting and inventory management, creating the need for intelligent and real-time supply chain applications [4] that can enforce the required balance between supply and demand based on actual market and patient needs [5].

The aim of this research is to explore through a bibliometric literature review the interconnection of DDSC with AI and ML in a pharmaceutical context in order to answer the following research question: "How does integrating AI and ML impact the transition toward DDSC in healthcare and the pharmaceutical industry?"

2. Materials and Methods

The BLR is based on the academic database Scopus, exploring the integration of AI and ML in the pharmaceutical industry and healthcare sector, with a specific orientation on demand and supply chain management. The main keywords related to "Artificial Intelligence," "Machine Learning," "Healthcare," "Pharmaceutical Supply Chains," and "Forecasting" were used for data collection, and for data visualization, the VOSviewer tool was applied to map relationships among these themes and extract quantitative insights.

The objective of this BLR is to explore where DDSC meets with AI and ML imperatives in the specific sector related to healthcare and pharmacy supply chains. To conduct this, a structured approach was followed to search for documents in the database Scopus using specific queries in order to select the most relevant articles and to analyze the data collected. Our advanced query is the following:

TITLE-ABS-KEY ((“pharmaceutical industry” OR “pharmaceutical supply chain” OR “pharma” OR “PSC” OR “healthcare”) AND (“demand driven” OR “demand-driven” OR “DD” OR “demand-driven supply chain” OR “DDSC” OR “forecasting” OR “forecasts” OR “Supply Chain” OR “SCM”) AND (“Artificial Intelligence” OR “AI”) AND (“Machine Learning” OR “ML” OR “Algorithm” OR “digital” OR “Digitalization” OR “blockchain” OR “Industry 4.0” OR “technology” OR “tool” OR “System” OR “Systems” OR “Platform” OR “Platforms” OR “bid data” OR “model” OR “models” OR “analyze”)) AND (LIMIT-TO (SUBJAREA, “BUSI”)).

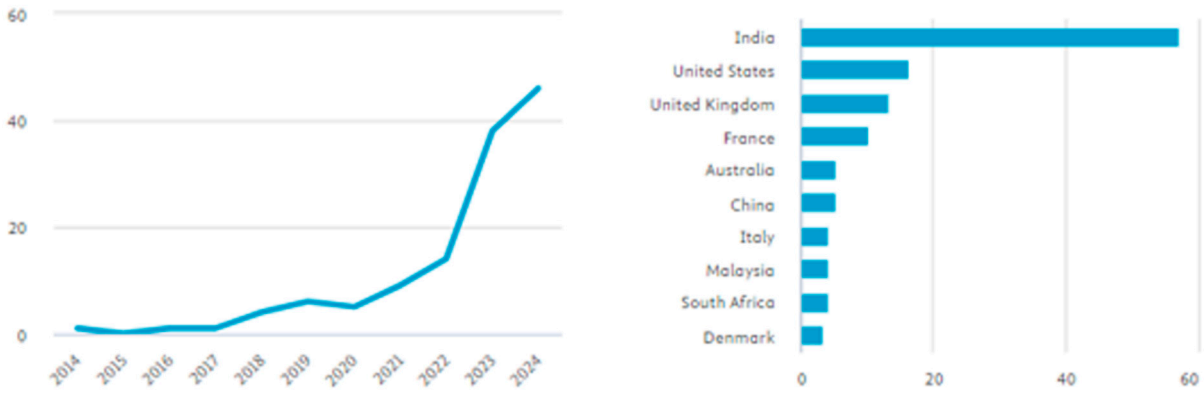
The final results were extracted as a CSV file in order to conduct a bibliometric analysis using VOSviewer (version 1.6.20) based on co-occurrence patterns.

3. Results

After applying the query described in the methodology, 129 documents were identified in Business Management and Economics, demonstrating recent advancements in AI and ML applications in pharmaceutical and healthcare supply chain management.

The results highlight the growing importance of AI and ML in healthcare and pharmaceutical supply chains, as demonstrated in Figure 1 below: panel (a) shows the progression of the number of documents per year, with the horizontal axis representing the years from 2014 to 2024, and the vertical axis representing the number of documents, ranging from 0 to 60. Panel (b) in the same figure showcases geographic contributions, with India leading in publications, followed by the U.S., U.K., and France, indicating regional leadership in AI/ML adoption for pharmaceutical supply chain advancements. This figure illustrates the significant rise in Scopus publications, especially from 2022 onwards, demonstrating the big interest in integrating AI and ML technologies into DDSC in alignment with the increased global focus on healthcare innovations post-COVID-19.

After conducting the bibliometric analysis using VOSviewer, a network visualization map was created, as shown in Figure 2, which reveals strong links between AI and ML, as well as between healthcare and supply chain management. This map also indicates that the connection between AI/ML and pharmaceutical supply chains is still underexplored compared to broader healthcare applications. While AI methods like forecasting, blockchain, and decision-support systems are linked to healthcare supply chains, specific applications unique to pharmacy logistics are relatively less represented.



(Documents by year) (Documents by country/territory)

Figure 1. Scopus results showing the number of documents by year and by country.

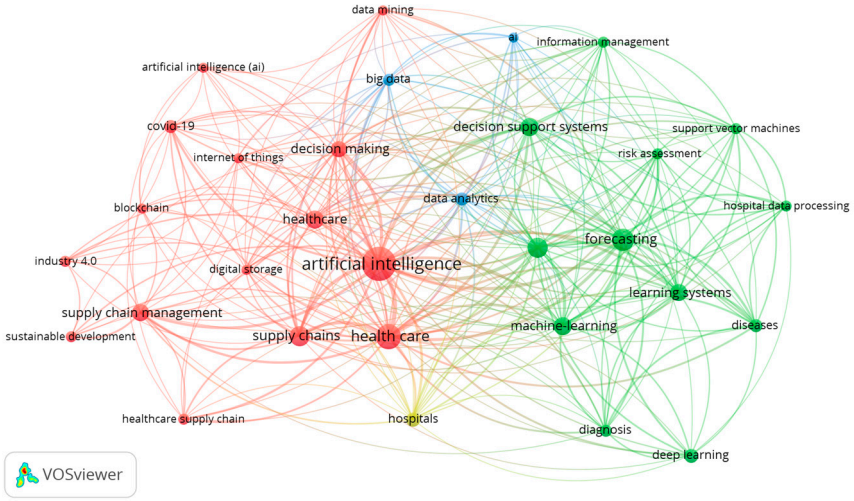


Figure 2. Visualization network for co-occurrence (source: authors using VOSviewer).

This bibliometric map reveals three main clusters:

1. Red Cluster (AI and Healthcare): This cluster highlights the role of AI, in general, in healthcare management, with strong connections to terms related to decision-making, digital storage, data mining, blockchain, and COVID-19. These links suggest that AI is primarily used for improving operational decision-making, patient outcomes, and tackling challenges that came about during or after and as a result of the pandemic.
2. Green Cluster (ML for Forecasting and Analytics): This cluster is centered around Machine Learning techniques, including forecasting, learning systems, and data analytics, showing how predictive tools are vital for demand planning, risk assessment, diagnosis, and hospital data processing.
3. Blue Cluster (Supply Chain and Logistics): Including nodes related to supply chain management, healthcare supply chain, and digital storage, which suggest applications of AI in streamlining logistics processes, optimizing inventory management, and enhancing transparency in pharmaceutical supply chains.

While this network map illustrates connections between these key topics, Table 1 provides quantitative metrics, including the frequency of keyword occurrences and their total link strength, indicating the depth and breadth of co-occurrence relationships.

Table 1. Keyword occurrences and links to strengths (source: authors using VOSviewer—Appendix A).

Grouping	Keywords	Occurrences	Link Strength
Technologies and Strategic Integration	Artificial Intelligence	52	210
	Healthcare and healthcare	44	203
	Machine Learning and machine-learning	34	190
	Supply chains and supply chain management	32	136
Operational Implementation and Impact	Forecasting	22	115
	Decision support systems and Decision making	28	142
	Learning systems	13	80
	Hospitals	10	51

The first group emphasizes the foundational role of AI and ML technologies in transforming the healthcare sector. The high occurrence and link strength indicate their central importance in driving healthcare and pharmaceutical supply chains.

The second group highlights the operational use of these technologies in enhancing operational efficiency and improving strategic decision-making. The focus on forecasting and decision support systems indicates a trend toward utilizing predictive models and data-driven insights for supply chain planning while indicating hospitals as one of their practical implementation sites.

This analysis shows a strong interconnection between the keywords and emphasizes the pivotal role of AI and ML in predictive analytics and decision support systems within supply chain management, demonstrating the growing impact of these technologies on healthcare and pharmaceutical supply chains.

4. Discussion: The Integration of AI and ML for a DDSC in the Pharmaceutical and Healthcare Sectors

The BLR results indicate significant potential for AI and ML in enhancing pharmaceutical supply chain efficiency and resilience. This can include the use of ML algorithms for predictive analytics, which address pharmacy-related disruptions in particular, such as those seen during the COVID-19 pandemic.

The literature highlights that the most significant impact of AI and ML algorithms on DDSC is their ability to enhance demand forecasting, improve inventory management, optimize logistics, and lead to a resilient supply chain [6]. In the upcoming subsections, this will be explored in terms of pharmaceutical and healthcare supply chains.

4.1. Improving Demand Forecasting

Accurate demand forecasting is crucial in the pharmaceutical and healthcare sectors to ensure the availability of essential medications and supplies. Both AI and ML algorithms have a strong capacity to analyze vast datasets, including historical sales, seasonal trends, and external factors, to predict demand with high accuracy. The higher the accuracy of demand predictions, the more effective the recovery strategies and the greater the resilience of the supply chain [5].

ML and AI technologies are increasingly used to monitor and forecast epidemic outbreaks and seasonal illnesses globally. This predictive demand enables more efficient supply chain planning by ensuring the availability of the right inventory with the appropriate quantity at the right time [7].

The existing literature shows that ML models, especially XGBoost, outperform traditional methods in pharmaceutical sales forecasting. Tailoring models to specific drug categories significantly improves demand accuracy [8]. Some models like BILSTM, LSTM,

and GASVR are demonstrated to achieve higher forecast accuracy, contribute to improved timeliness and precision in predicting healthcare resources, and enhance demand forecasting dynamics [9].

In some cases, limited data, changing market conditions, and hidden demand pose challenges and influence advanced demand forecasting models. To overcome these issues, some studies introduce an innovative framework that uses cross-series training, leveraging time series data from multiple products and advanced ML models for pattern detection [10].

4.2. Enhancing Inventory Management

Machine Learning algorithms process extensive historical data to detect patterns and trends, allowing for more precise predictions and, consequently, optimizing inventory adjustments [11].

Effective inventory management ensures that pharmaceutical and healthcare facilities maintain optimal stock levels, minimizing both shortages and obsolescence by monitoring inventory in real time, predicting patterns of usage, and automating ordering processes [12].

4.3. Optimizing Logistics

The implementation of AI and ML into supply chain processes significantly improves operational efficiency. The application of ML algorithms enhances logistics by improving routing, optimizing scheduling, reducing transit times, lowering fuel consumption, and warehousing automation through robotics and automated sorting, leading to streamlining workflows, minimizing human error, and boosting productivity [13].

4.4. Supply Chain Resilience

By providing accurate predictions, AI and ML help organizations to better prepare for uncertainties, adopt proactive risk management strategies, and respond quickly to sudden supply chain disruptions, especially the ones caused by pandemics or natural or geopolitical disasters [14,15].

In short, the integration of AI and ML into pharmaceutical and healthcare supply chains offers various benefits, including improved demand forecasting, optimized inventory management, efficient logistics, and enhanced resilience against supply chain disruptions. In addition to real-time decision-making, customer service improvement, fraud detection, and risk management, multiple companies have oriented their strategies toward implementing those technologies. Table 2 gives some examples from the pharmaceutical industry. This list is not exhaustive; also, the companies mentioned are cited exclusively for illustrative and academic purposes, with no other interest influencing their inclusion.

Table 2. AI and ML technologies implemented in the pharmaceutical supply chain.

AI Technology	Key Features	Example in Pharmacy Industry
SAP Integrated Business Planning Software	Data forecasting Response and supply planning Sales and operations planning Inventory planning and optimization	Novo Nordisk AstraZeneca Pfizer
Kinaxis Maestro (RapidResponse)	Supply chain planning and orchestration Key performance indicators (KPIs) driving decision-making	Pfizer
Blue Yonder	Cold chain logistics management Delivery optimization (delivery route and schedule)	Bayer

5. Conclusions

This BLR indicates significant potential for AI and ML in enhancing pharmaceutical supply chain efficiency and resilience. This can include the use of ML algorithms for predictive analytics, which addresses pharmacy-related disruptions in particular, such as those seen during the COVID-19 pandemic. The quantitative data in the network visualization showcases the relative dominance of healthcare-related themes over supply chain topics, underscoring the need for targeted studies to address gaps in areas such as pharmacy logistics, cold chain management, and vaccine distribution systems.

The implementation of blockchain technology can also be leveraged for an effective traceability system to determine the follow-up of drug transaction flows [16].

Future studies can be explored focusing on empirical validations of the impact of DDSC models and the application of AI and ML to develop Moroccan healthcare systems while also focusing on identifying the challenges of these implementations.

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Data Availability Statement: The datasets analyzed and generated during the study are available in Scopus.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Source for Table 1:

Selected	Keyword	Occurrences	Total link strength
☑	artificial intelligence	52	210
☑	health care	29	151
☑	forecasting	22	115
☑	machine learning	19	101
☑	supply chains	18	87
☑	decision support systems	16	82
☑	machine-learning	15	89
☑	healthcare	15	52
☑	supply chain management	14	49
☑	learning systems	13	80
☑	decision making	12	60
☑	hospitals	10	51

References

1. Mendes, P.; Leal, J.E.; Thomé, A.M.T. A maturity model for demand-driven supply chains in the consumer product goods industry. *Int. J. Prod. Econ.* **2016**, *179*, 153–165. [CrossRef]
2. Majda, B.; Farouk Imane, I.E. Demand-Driven Supply Chain Harmonizing Digitalization, Resilience, and Sustainability: Exploring the Synergy through a Bibliometric Literature Review. In Proceedings of the 2024 IEEE 15th International Colloquium on Logistics and Supply Chain Management (LOGISTIQUA), Sousse, Tunisia, 2–4 May 2024; pp. 1–7.
3. De Mattos, C.A.; Correia, F.C.; Kissimoto, K.O. Artificial Intelligence Capabilities for Demand Planning Process. *Logistics* **2024**, *8*, 53. [CrossRef]
4. Dreyer, H.C.; Strandhagen, J.O.; Romsdal, A.; Hoff, A. Principles for Real-Time, Integrated Supply Chain Control: An Example from Distribution of Pharmaceuticals. In *Advances in Production Management Systems. New Challenges, New Approaches*; Vallespir, B., Alix, T., Eds.; IFIP Advances in Information and Communication Technology; Springer: Berlin/Heidelberg, Germany, 2010; Volume 338, pp. 187–194, ISBN 978-3-642-16357-9.

5. Yani, L.P.E.; Aamer, A. Demand forecasting accuracy in the pharmaceutical supply chain: A machine learning approach. *IJPHM* **2023**, *17*, 1–23. [CrossRef]
6. Boualam, M.; Ibn El Farouk, I.; Jawab, F. Revolutionizing the Demand-Driven Supply Chain: AI and Machine Learning Applications. In *Supply Chain Transformation Through Generative AI and Machine Learning*; Sabri, E., Ed.; IGI Global Scientific Publishing: Hershey, PA, USA, 2025; pp. 347–378, ISBN 9798369344330.
7. Subroto, M.; Kathleen, W. The Increasing Use of AI In The Pharmaceutical Industry 2020. Available online: https://www.forbes.com/sites/cognitiveworld/2020/12/26/the-increasing-use-of-ai-in-the-pharmaceutical-industry/?sh=1d3a80124c01 (accessed on 15 January 2025).
8. Fourkiotis, K.P.; Tsadiras, A. Applying Machine Learning and Statistical Forecasting Methods for Enhancing Pharmaceutical Sales Predictions. *Forecasting* **2024**, *6*, 170–186. [CrossRef]
9. Zhang, W.; Li, X. A data-driven combined prediction method for the demand for intensive care unit healthcare resources in public health emergencies. *BMC Health Serv. Res.* **2024**, *24*, 477. [CrossRef] [PubMed]
10. Zhu, X.; Ninh, A.; Zhao, H.; Liu, Z. Demand Forecasting with Supply-Chain Information and Machine Learning: Evidence in the Pharmaceutical Industry. *Prod. Oper. Manag.* **2021**, *30*, 3231–3252. [CrossRef]
11. Kumar, P.; Choubey, D.; Amosu, O.R.; Ogunsuji, Y.M. AI-enhanced inventory and demand forecasting: Using AI to optimize inventory management and predict customer demand. *World J. Adv. Res. Rev.* **2024**, *23*, 1931–1944. [CrossRef]
12. AI for Supply Chain Management in Healthcare: Optimizing Inventory and Reducing Waste 2024. Available online: https://www.bluebash.co/blog/ai-supply-chain-healthcare-optimizing-inventory-waste/ (accessed on 15 January 2025).
13. Muthaluri, J. Optimizing Supply Chain Management And Marketing Strategies: AI And ML Integration For Competitive Advantage. *Educ. Adm. Theory Pract.* **2024**, *30*, 8990–8997. [CrossRef]
14. Gupta, S.; Modgil, S.; Meissonier, R.; Dwivedi, Y.K. Artificial Intelligence and Information System Resilience to Cope With Supply Chain Disruption. *IEEE Trans. Eng. Manag.* **2024**, *71*, 10496–10506. [CrossRef]
15. Sullivan, Y.; Wamba, S. Artificial Intelligence, Firm Resilience to Supply Chain Disruptions, and Firm Performance. In Proceedings of the 55th Hawaii International Conference on System Sciences, Virtual, 4–7 January 2022.
16. Uddin, M.; Salah, K.; Jayaraman, R.; Pesic, S.; Ellahham, S. Blockchain for drug traceability: Architectures and open challenges. *Health Inform. J.* **2021**, *27*, 14604582211011228. [CrossRef] [PubMed]

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