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A scientometric review of the blood supply chain literature (2010-2025): Evolution, trends, and intellectual structure

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C H R O N I C L E

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A B S T R A C T

The blood supply chain (BSC) is a crucial and intricate system in the healthcare sector, which is marked by perishable products, fluctuating supply and demand, and a major impact of inefficiency. This paper showcases a detailed scientific review of BSC literature from 2010 to 2025 through scientometric methods, thereby mapping out its intellectual structure and development. By scrutinizing both foundational and recent publications, the authors are able to point out the research streams, methodological trends and main scholars. The scrutiny brings forward three leading research paradigms: (1) robust and resilient network design for disaster response, with Jawad as the leading scholar; (2) green and sustainable BSC modeling under uncertainty, where Pishvaee and his team are the main contributors; and (3) integrated inventory-routing problems for perishables, with Ramezanian as the pivotal author. This discipline is moving away from deterministic, single-objective models to the development of intricate multi-objective frameworks under hybrid uncertainties (robust, fuzzy, stochastic) which are being solved increasingly with metaheuristics and supported by case studies from real applications. The new trends include the combination of AI/ML for forecasting and decision-making, blockchain for transparency, and drones for the delivery part. The present review collects all these advancements and gives a succinct direction for both researchers and practitioners.

1. Introduction

The blood supply chain (BSC) represents an essential element of the healthcare system all over the world, as it is responsible for the safe, timely, and efficient blood and its components availability for transfusion. Its management, however, comes with unique difficulties, such as the perishable nature of blood products (e.g., red blood cells have a 42-day shelf life), the uncertain availability of the supply based on voluntary donations, and stochastic and critical demand (Pierskalla, 2005). The combination of these three factors—perishability, supply volatility, and demand uncertainty—creates a complex operational environment that allows inefficiencies to cause severe shortages, which can endanger patients, or significant wastages of a precious resource (Osorio, Brailsford, & Smith, 2017; Chien, Yao, Chen, & Ho, 2025). The BSC's weakness is made worse by its dependence on external disruptions like natural disasters and pandemics that can lead to immediate, drastic increases in demand, while at the same time, making it impossible to collect blood (Jabbarzadeh, Fahimnia, & Seuring, 2014; Yang et al., 2025). Researchers have consequently been focusing the entire time on optimizing this crucial supply chain that has gradually transformed from simple deterministic stock models to very sophisticated multi-echelon networks capable of simultaneously satisfying conflicting objectives such as minimum costs, less waste and high service level (Beliën & Forcé, 2012; Hosseini-Motlagh, Samani, & Kordhaghi, 2026). The area is now more and more frequently combining resilience and sustainability concepts in its research, targeting the creation of systems that are not only efficient in normal operation but also able to withstand disruptions and eco-friendly (Pishvaee, Razmi, & Torabi, 2014; Sheibani, Ostovari, & Benyoucef,

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2025). This has resulted in the usage of modern modeling methods such as robust and fuzzy possibilistic programming in order to deal with these uncertainties and multi-objective trade-offs that are intrinsic to the system (Pishvaee, Rabbani, & Torabi, 2011; Ala, Simic, Bacanin, & Tirkolaee, 2024).

Research to the optimization of the BSC has indeed broadened usage if the past fifteen years (2010-2025) are taken into consideration. Instead of just sticking to the foundational inventory models, it has been done with complexities of multi-echelon network design incorporating problems that the uncertainty, disruption, and sustainability issues pose. Merging through foundational studies around 2010, the research as well as the new methodologies have developed so fast. As an example, Jabbarzadeh et al. (2014) came up with a resilient supply chain design that is based on robust optimization and is able to withstand disruption, which is already a very important issue. The same goes for Pishvaee et al. (2011) who gave birth to fuzzy probabilistic programming that can cope with epistemic uncertainties in supply chain design. The methodology has found its way into and has been accepted in the BSC context as Per Pishvaee & Razmi, 2012; Pishvaee, Rabbani, & Torabi, 2011. In addition, researchers like Ramezanian and Behboodi have worked on blood supply chain in supply and demand by considering social aspects (Ramezanian & Behboodi, 2017).

Although there are narrative reviews, a quantitative, scientometric analysis that covers the whole intellectual territory—from the basic works to the most recent ones—is missing. This investigation intends to the area of concern and accordingly, the following research queries are raised:

1. Who are the main writers that had the most impact and which among their works can be considered the most important for the development of BSC research from 2010 to 2025?
2. List down few of the leading methodological approaches (possibly of their most conspicuous shifts in the form of solution strategy or handling of uncertainty) that have evolved during the perceptive period.
3. What are some basic themes in research and future directions for inquiry that you think would organize themselves over time?

2. Methodology

This assessment is founded on a methodical evaluation of major BSC literature that has been published from 2010 to 2025. The evaluation combines results from two main sources:

1. **Foundational Works:** A focal point for this chapter will be identifying key, highly-cited papers following a traditional literature review and citation mapping, with primary authors being Jabbarzadeh, Pishvaee, and Ramezanian.
2. **Contemporary Literature:** The dataset is the collection of 250 recent publications in the period spanning 2010 and 2026 selected by using Scopus, for the sole purpose of re-emphasizing the ongoing trends and validating the continuity of previous ones.

The literature was coded and analyzed based on:

- **Influence:** Measured by global citation count and recurring recognition in review papers.
- **Solution Strategy:** Categorized as Exact Methods, Metaheuristics, or Hybrid approaches.
- **Objective Function:** Classified as Single-Objective or Multi-Objective.
- **Uncertainty Modeling:** Identified as Robust Optimization, Fuzzy Programming, Stochastic Programming, or hybrid methods.
- **Research Focus:** Thematic categorization (e.g., Network Design, Resilience, Sustainability, Inventory-Routing).

3. Results and Discussion

1. The Intellectual Foundation: Foundational Works and Influential Scholars

Table 1 illustrates that the intellectual basis of BSC research has been laid down by a group of notable researchers. Their pioneering publications provided strong and versatile methods—from resilient network design to fuzzy possibilistic programming—that created lasting paradigms and still hold a lot of power in the contemporary research arena.

Table 1
Foundational and Highly-Cited Works in Blood Supply Chain Research (2010-2025)*

Research Focus	Key Authors & Seminal Works	Core Contribution	Methodological Impact
Resilient Network Design under Disruption	Jabbarzadeh et al. (2014, 2016); Fahimnia et al. (2017)	Developed robust optimization models for designing BSCs that are resilient to disruptions from disasters, introducing strategies like strategic inventory pre-positioning and backup facilities.	Established robust optimization as a gold standard for disaster-relief BSC design.
Green/Sustainable BSC under Uncertainty	Pishvaee et al. (2011, 2012, 2014); Zahedi et al. (2021)	Pioneered the use of fuzzy possibilistic programming and multi-objective models to incorporate environmental and social objectives alongside cost, under supply and demand uncertainty.	Popularized fuzzy programming for epistemic uncertainty and integrated sustainability into BSC objectives.
Perishable Inventory & Integrated Logistics	Ramezanian & Behzadi (2012); Ramezanian et al. (2013); Zahiri et al. (2014)	Focused on multi-period inventory-routing problems for perishable products, developing robust and possibilistic models to balance wastage and shortage.	Advanced integrated operational-tactical planning and robust modeling for perishability.
Stochastic & Multi-Objective Models	Duan & Liao (2013); Samani et al. (2017); Sha & Huang (2012)	Advanced two-stage stochastic programming and sophisticated metaheuristics for multi-objective BSC optimization under demand uncertainty.	Enhanced the handling of operational uncertainty and the trade-off between competing objectives.

2. Evolution of Methodological Approaches

The analysis of both foundational and recent literature reveals a clear evolution in methodological sophistication.

2.1. From Single to Multi-Objective Optimization

The first attempts at modeling blood supply chain (BSC) management were primarily based on a single-objective paradigm, where the main aim, and often the only one, was to cut down total costs for the whole system. This kind of focus is illustrated by the basic network design models that aimed to find the best location for facilities and the most efficient transportation of goods purely from an economic point of view (Jabbarzadeh et al., 2014). Nevertheless, the area has entirely and massively shifted towards multi-objective optimization frameworks, which is a significant and a very clear paradigm shift. This change is an indication that costs, the least one of the BSC performance metrics, cannot be used to describe the whole BSC performance anymore, instead, it is a matter of winning and losing through a very careful and simultaneous balancing of priorities that are usually at odds. Economic considerations still play an important role, but they are now being systematically measured against the most important service-level indicators, such as, delivery time reduction to save lives during emergencies and preventing hospitals from running out of the needed blood (Fariman et al., 2024; Hosseini-Motlagh et al., 2026). Besides that, the list of objectives has been widened to cover the sustainability issue which is becoming more and more urgent; thus, the environmental aspect is being taken into account like the logistical carbon footprint reduction from the hospitals and also the social aspect like the raising of employment and making sure that the blood services are fairly accessible to different regions (Pishvaee et al., 2014; Sheibani et al., 2025).

In turn, the current BSC research is marked by intricate and diverse objective functions. It has become common practice to observe models that optimize together cost and time in disaster relief, cost with wastage and shortage in daily inventory management to tackle the main problem of perishability, and cost with carbon emissions and social responsibility to create supply chains that are both ethically and ecologically aware (Fariman et al., 2024; Altunoglu & Batur Sir, 2024; Lusiantoro, Mara, & Rifai, 2024). The above mentioned trend requires one to employ sophisticated multi-objective metaheuristics and decision-making techniques to get through these trade-offs and deliver Pareto-optimal solutions to the decision-makers, thus highlighting the field's transition from a mere cost-focused view to a comprehensive performance management perspective as it has matured.

2.2. The Ascendancy of Metaheuristics and Hybrid Methods

The multi-objective blood supply chain models' complexity, which is the reason why they are often NP-hard, combines their location, allocation, inventory, and routing decisions under uncertainty into a single problem that necessitates sophisticated solution strategies. Metaheuristics have, for sure, secured themselves as the major and most widely accepted solution methodology during the time when high-dimensional and complicated solution spaces must be explored. These algorithms are considered to be of a high level and conducted search type; their performance might not reach global optimum but they are remarkable in the quality and proximity of the found solutions to the Pareto front, which indicates the collection of non-dominated trade-offs among conflicting objectives. The choice of the specific algorithm among many has been made and some of them become the standard in the BSC research community. The Non-dominated Sorting Genetic Algorithm II (NSGA-II) is usually opted for its skillful management of different objectives, while Multi-Objective Particle Swarm Optimization (MOPSO) is appreciated for its rapid convergence and social learning principles (Karamipour & Agha Mohammad Ali Kermani, 2024; Alikhani, Dezfoulian, & Samouei, 2024).

Researchers keep on benchmarking and adapting various meta-heuristics such as Invasive Weed Optimization (IWO) and Symbiotic Organism Search (SOS) to the specific limitations of perishable items and uncertain environments (Khameneh et al., 2023; Ndlalane et al., 2024). Nonetheless, even more complicated problems—like large-scale, multi-stage stochastic models that have to make "here-and-now" decisions before uncertainty resolution and "wait-and-see" decisions thereafter—might require more than pure metaheuristics. For these difficult problems, hybrid methods that unite the strengths of exact mathematical programming with the flexibility of metaheuristics are becoming the new gold standard. One of the most common and effective strategies is to embed metaheuristics into decomposition frameworks, e.g., using a genetic algorithm to take care of the high-level strategic choices (like facility location) and at the same time applying Benders Decomposition or Column Generation to efficiently solve the resulting operational sub-problems (such as distribution and allocation) (Abdolazimi et al., 2025; Qing et al., 2025; Elyasi et al., 2025). This hybrid model gives an opportunity to researchers to work on the integrated strategic and operational planning of robust and sustainable blood networks with a degree of precision and scalability that was previously unfeasible.

2.3. Sophisticated Uncertainty Modeling

Handling uncertainty remains a core challenge. The foundational work established three main streams:

- **Robust Optimization (RO):** Following Jabbarzadeh et al. (2014), RO is preferred for worst-case scenario planning in disaster relief and high-disruption models (Wang & Chen, 2025; Feghhi et al., 2025).
- **Fuzzy Possibilistic Programming (FPP):** Building on Pishvaee et al. (2011), FPP is widely used for parameters with epistemic uncertainty, such as costs and capacities (Hosseini-Motlagh et al., 2026; Erdem & Ozdemir, 2025).
- **Stochastic Programming (SP):** Used for operational problems where demand can be modeled with scenarios (Casucci et al., 2024; Yang et al., 2025).

A key recent trend is the development of hybrid uncertainty models that combine these approaches for greater realism (Esfandabadi et al., 2024).

Table 2
Predominant Methodological Trends in Contemporary BSC Research (Based on 250 Recent Publications)

Aspect	Category	Prevalence	Representative References
Solution Strategy	Metaheuristics	Dominant	Karamipour et al. (2024); Alikhani et al. (2024)
	Hybrid/Heuristic	High (for complex problems)	Abdolazimi et al. (2025); Elyasi et al. (2025)
	Exact Programming	Moderate	Diglio et al. (2024); Casucci et al. (2024)
Objective Function	Multi-Objective	Overwhelmingly Dominant	Sheibani et al. (2025); Hosseini-Motlagh et al. (2026)
	Single-Objective	Low	Motamedi et al. (2024)
Uncertainty Modeling	Robust Optimization	Very High	Wang & Chen (2025); Feghhi et al. (2025)
	Fuzzy Programming	Very High	Hosseini-Motlagh et al. (2026); Erdem & Ozdemir
	Stochastic Programming	High	Yang et al. (2025); Casucci et al. (2024)

3. Key Research Themes and Emerging Frontiers

The intellectual structure of BSC research can be mapped to several key and emerging themes.

3.1. Core Research Streams

- **Resilience and Disruption Management:** The research sphere that was started off by Jabbarzadeh et al. (2014) is still very much alive. The current research trend is about using UAVs/drones for delivery (Wang & Chen, 2025; K N & M, 2025), lateral transshipment (Qing et al., 2025), and robust network design for specific disasters (Feghhi et al., 2025).
- **Sustainability:** The combination of environmentally friendly goals, set in motion by Pishvaee et al. (2014), has become a universal concern. Transport carbon emissions are a topic now covered by research along with (Lusiantoro et al., 2024), social dimensions such as job equity and creation (Sheibani et al., 2025), and the application of circular economy principles.

- **Integrated Operational Planning:** According to Ramezanian & Behzadi (2012), this direction of research has been very much synonymous with automating the decision-making process for perishables by AI, however, the latter has become quite common practice in the supply chain field (Mohamadi et al., 2024).

3.2. Emerging Frontiers

- **Technology Integration:** There is a dramatic increase in the studies which make use of the Industry 4.0/5.0 technologies. Demand forecasting is done using AI and machine learning (Abolghasemi et al., 2025) and reinforcement learning (Mohamadi et al., 2024). On the other hand, block-chain technology is proposed for improving the traceability and security of transactions (Ailane et al., 2025; Kumar et al., 2024).
- **Personalized and Precision Transfusion Medicine:** Supply Chain Management (SCM) is gradually associating with medical breakthroughs through research, for instance, the creation of red blood cell genotype databases for exact matching (Feng et al., 2025), which is a step towards a more patient-centric supply chain.

4. Conclusion and Future Directions

This scientometric review has comprehensively and systematically mapped the great evolution of Blood Supply Chain (BSC) research, which is always dynamic, over the key time of years, 2010-2025, and thus the research is very complex for a single discipline. The analysis uncovers the maturation of the field through a clear line of development: the field has made it through the basics of single-objective, cost-based models that used to deal with uncertainty mostly through stochastic or early robust approaches (Jabbarzadeh et al., 2014) to the present-day status of a smart, multi-faceted discipline that fully acknowledges the complexities of real-world systems. The current trend in research is essentially defined by the use of multi-objective optimization, where the economic cost is rigorously weighed against the critical performance measures including recovery of wastage and prevention of shortage (Mansur, Wangsa, Rizky & Vanany, 2025), shortening of emergency response time (Fariman et al., 2024), and increasing the levels of service in hospital networks (Hosseini-Motlagh et al., 2026). Besides the above, the paradigm now allows for the explicit preparation of the system to absorb the impact of disasters and pandemics and at the same time to be guided by the principles of eco-friendly system design such as carbon footprint minimization and social objectives like equitable distribution of benefits and creating jobs (Wang & Chen, 2025; Qing et al., 2025; Sheibani et al., 2025; Ailane et al., 2025). The pace of this change is greatly influenced by the ever-greater use of cutting-edge technologies, such as the use of AI and machine learning for the purpose of predictive forecasting and dynamic decision-making (Abolghasemi et al., 2025; Mohamadi et al, 2024), blockchain being investigated as a means of assuring traceability and security (Kumar et al., 2024), and drone technology being applied to last-mile delivery that is robust and resource-efficient (K N & M, 2025). Thus, the current literature on BSC depicts a well-matured integration of operations research, sustainability science, and digital innovation that is capable of creating the smart, resilient, and efficient blood supply systems which are the demand of modern healthcare.

The pioneering research of Jabbarzadeh, Pishvaee, Ramezanian, and their fellows laid down the basic mathe-matical structures which the domain relies on. The cutting-edge of the field is indicated by the mixture of both solution methods and uncertainty models along with their application to intricate, real-life problems as case studies.

Future research should focus on:

1. **Human-AI Collaboration:** The development of models that bring together human decisions (e.g., donor behavior or clinical practice) and AI-related optimization efficiently.
2. **Interoperability of Technologies:** As for now, the current trend follows integration of IoT, Notion Intelligence, and Blockchain. These provide foundational elements for managing the BSC in the smart mode.
3. **Climate Change Adaptation:** The effects of climate-induced disruptions form a model for environmentally related parameters as well as strategy, that affects the perspective of the Balanced Scorecard as described in detailed by Viennet (2005).
4. **Standardized Performance Metrics:** One set of metrics should be developed in order to evaluate how resilient, sustainable,and efficient different BSC designs are.

BSC research will continue to provide critical insights for saving lives and optimizing healthcare resources by continuing to build on its strong intellectual foundation while embracing these new frontiers.

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