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Review

A Review of Blood Delivery for Sustainable Supply Chain Management (BSCM)

Saleh Y. Alghamdi

Department of Industrial Engineering, College of Engineering, King Khalid University, Abha 61421, Saudi Arabia; syalghamdi@kku.edu.sa

Abstract: The management and supply of blood are critical yet considered a challenging exercise within the healthcare industry. The inventory managers within the sector concerned with blood storage and transportation always focus on their consumers' effective and timely responses. A lack of blood during emergencies significantly impacts patients' lives needing a blood transfusion. On the other hand, blood transfusion to needy patients must be effective and timely, requiring adequate transportation and supply chain policies. A weak transportation system could lead to blood shortages, delivery inefficiencies, and even contamination during the process. There are few blood donors globally; therefore, any wastage due to a poor delivery solution is ineffective. The current review aims to offer a comparative study of blood delivery within crowded cities, specifically using cars and motorcycles as the leading delivery solutions. Based on the systematic literature review, the most effective and responsive blood delivery system in a congested city may be identified considering SC costs, time availability, and emergency severity. The present research provides a comparative analysis of the available blood delivery systems in a congested city. It also helps the stakeholders to take quick and responsive decisions quickly.

Keywords: blood delivery solutions; blood transfusion; blood supply chain management (BSCM); sustainable blood delivery

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1. Introduction

Most countries have departments within the healthcare system dealing with blood delivery and supply chain services. Developed countries invest heavily in healthcare and do everything to ensure that their populations are equipped with efficient healthcare services, including an adequate blood supply [1]. The last-mile delivery of perishable products like blood in a supply chain is a very critical issue as it involved economic challenges, environmental challenges, and social needs [2]. In many countries, access to blood and blood products having a short life cycle is still problematic as it goes through a complex supply chain with demand fluctuation at the hospital level.

Blood products are essential commodities in hospitals required during emergencies; therefore, banks should always remain stocked. Sufficient blood supply is achieved through an efficient supply chain and delivery system involving various processes, such as donation, transportation, and storage [3]. When choosing the best delivery solution, the supply chain personnel consider many factors; for instance, the access time for critically injured individuals highly depends on the efficiency and effectiveness of the delivery solution. When managing emergency services, blood supply chain management (BSCM) presents several challenges.

Several aspects of blood require an efficient delivery solution. Firstly, it contains numerous components with a different shelf life; secondly, the preparation process of different components is costly; therefore, eliminating wastage is essential. Moreover, the donor locations and dates may differ, requiring efficient delivery planning. Cars and motorcycles have been adopted in different crowded cities globally. These delivery

solutions have attracted positive and negative aspects, influencing the primary goal of offering fast, cost-effective delivery of well-maintained blood conditions.

The management of blood supply is very critical and needs accuracy in its sourcing, planning, processing, and distribution for its effective and responsive use. The operational process of BSM may be accomplished in five echelons as shown in Figure 1a whereas the blood centers can be grouped into five categories as shown in Figure 1b either at the same place or geographically dispersed places which facilitate fixed collection sites or mobile collection sites. The blood supply chain (BSC) in both cases is compared against the collection quantities, transportation cost, and time. Various authors have carried out their research to optimize blood collection, transportation costs, and time. From the review of the literature, it has been revealed that researchers have considered the BSC management problem as a single echelon, double echelon, or three echelons.

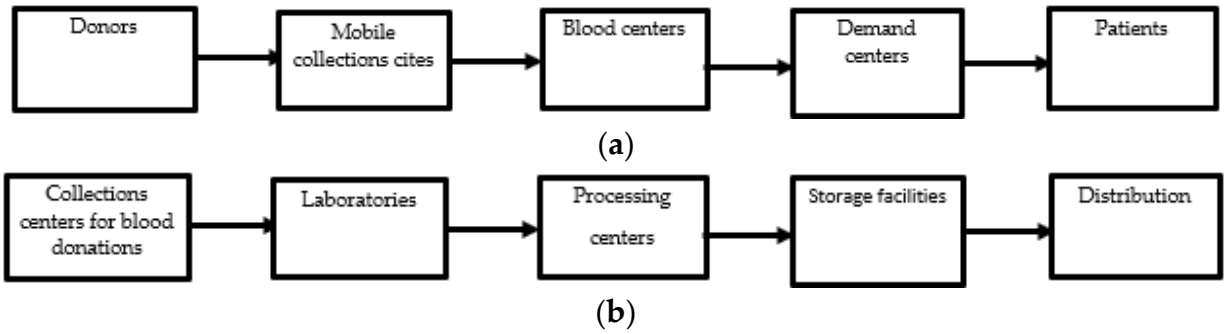

Figure 1. (**a**) Blood supply operational process. (**b**) Categories of blood collection centers.

The challenges encountered in BSC management are high wastage level, ability to predict demand for blood, low level of centralization in developing countries, unexpected short-term changes in demand, and sanitary, environmental, and infrastructural risks [4]. Further, wastes were found primarily as a result of incorrect temperature during transit, compromising blood bags' safety, and lack of equipment maintenance, leading to higher depreciation rates and waiting time for the delivery of biomolecular testing results. Looking at the various problems arising in the BSC, the following research questions are considered significant for the present research: What is the present research on blood supply chain management? How can a comparative study of blood delivery systems within crowded cities, specifically using cars, motorcycles and drones can be carried out? and How can an efficient and cost-effective blood delivery system be identified?

The paper is further arranged as under: A literature review on BSCM is included in Section 2. Section 3 describes the research methodology of collecting research papers on BSCM for sustainable delivery. Section 4 provides the results. Section 5 documents the BSCM discussion for a sustainable delivery system. Finally, Section 6 offers findings, limitations, and future studies concerning BSCM.

2. Literature Review

In essence, BSCM is a prominent study area that numerous researchers have studied and analyzed. Several review-based studies have been taken up in past. The review was carried out based on 98 research papers in the area of inventory and SCM of blood products [5]. Further, they identified eight trends: type of blood product, solution method, hierarchical level, type of problem, type of approach, exact versus heuristic, performance measures, and practical implementation/case studies. Using quantitative models, an assessment of the BSC was conducted providing a taxonomic and associated framework for decision-making [6]. They classified models into five categories covering four stages (echelons) in the SC i.e collection, production, inventory, and delivery, and 'integrated' models covering more than one stage. A review of various techniques and models used in the BSC was analyzed and classified covering the papers published between 2005 and February 2019 [7]. The review of the blood-collecting quantitative models is based on

various processes appointment scheduling, collection policy, crisis, donor demographics, location/clinic planning, staff utilization, and vehicle routing [8]. They also analyzed the existing literature concerning methods, modeling objectives, and the planning levels such as strategic, tactical, and operational. A review was carried out for quantitative models used in the BSC related to a disaster situation published between 2018 to 2022 [9]. A review was conducted by reviewing 485 research papers from 1990 to 2021 to identify trends and potential areas for future BSC research [10]. The research revealed author influence, affiliation statistics, citation analysis, co-citation analysis, keyword analysis, and co-word analysis. A review considering the uncertainty in the BSC network was carried out [11]. Based on the literature between 2013–2022, they considered BSC phases characterization, relevant models published according to the strategic-tactical and operational-tactical perspectives, and capturing the sustainability dimensions treated in previous studies. A review of blood supply modeling for decision-making considering strategic to tactical levels was undertaken [12]. To solve the SC model and achieve much-needed sustainability (economic viability, environmental protection, and social equity) using drone technology, a special case of goal programming, i.e., preemptive in fuzzy environments, was used [2]. The results show the degree to which distribution hubs and drones may be strategically placed to distribute blood sustainably. Drone delivery for blood transport had a significant impact on inventory management of blood products and the resolution of health issues, with a decrease in on-hand inventory and wastage observed by adopting drone delivery. Furthermore, no efficacy was observed following road paving. It was also observed that there were improved health outcomes and in-hospital mortality [13–15]. Thus drones can be considered a viable option to use for last-mile delivery cases.

Blood transportation by cars and motorcycles has had a long history in developed countries, including; the United States, Japan, the United Kingdom, Brazil, and Australia. While selecting the transportation system, healthcare facilities consider numerous factors to ensure that desired quality is achieved. Many studies have analyzed the use of cars and motorcycles for blood transportation. The review mapped the literature based on different criteria; data were obtained from various databases, including Academic Search Premier, Web of Science, Scopus, and PubMed. This criterion informed the identification of relevant data relating to blood delivery within crowded cities.

Developed countries use cars for blood transportation since it is cheaper than other methods. A study by [16] investigated the effectiveness of a drone and an ambulance for blood transportation based on an economic perspective within two target hospitals. The study utilized cost-effective analysis (CEA) and activity-based costing (ABC) methods to analyze the cost of each delivery method. The study found that ambulance travel utilized approximately $9 per minute compared to $17.17 per minute by a drone [16]. This makes car transportation effective for institutions seeking cheaper blood delivery solutions.

The use of aerial drone technology has improved medical services, particularly blood transportation [17]. The use of drone technology has a huge impact on sustainability and may be referred to as “last-mile delivery”. The usage of drones must be assessed in light of social benefits, costs, and CO_2 emissions. It was suggested to use a mathematical model based on multi-objective targeting last-mile delivery. The preference for using drones in achieving sustainability was further demonstrated by confronting drones and commercial vehicles [2]. The drone technology helps in providing last-mile delivery by focusing on CO_2 emission, operating costs, and social benefits [2]. The use of drones can represent gains in delivery time, allowing a ‘just-in-time’ model of distribution of blood, operating through a ‘pull’ system, reducing the need for inventories and costs [4]. Drone technology has offered an improved opportunity in the healthcare sector, primarily in remote and/or underserved environments by decreasing lab testing turnaround times, enabling just-in-time lifesaving medical supply/device delivery, and reducing costs of routine prescription care in rural areas [17]. During health emergencies, drone plays a significant role in blood supply management in remote areas in developing countries [18].

Transportation by car is suitable for all blood components compared to other methods. A study was carried out to analyze blood storage and transportation history [19]. It was concluded that during the long-distance transportation of blood containing all the components, having required temperatures of between 2 to 6 °C, deterioration will not occur. The study found that different transportation modes in crowded cities would affect the levels of hemoglobin concentration, which affects proper blood maintenance. It has also been argued that the use of unmanned aircraft systems (UAS) has fine vibrations from its inbuilt jetfoil that could result in blood degradation even within the recommended temperatures [20]. Deliveries by cars proved effective when the blood had to be in transit for more hours since it can sustain the weight even in a traffic jam.

Transporting some components in congested cities, including red blood cells, can be done effectively by cars. A study by [21] determined that most Japanese hospitals obtained blood from medical facilities and made effective home transfusions using cars. The study compares the transportation of red blood cells (RBC) by car using three transportation toolkits of 'an active transport refrigerator (ATR)', 'a cooler box', and a 'Styrofoam box'. The study determined that although oscillations during a car ride can induce hemolysis of the red blood cells even under a controlled temperature, adopting a Styrofoam box or an ATR could minimize oscillations. Minimal hemolysis is detected by the erythrocytes' blood quality, minimizing its wastage, especially in crowded cities.

In crowded cities where traffic is frequent, blood deliveries by road are efficient since cars have plenty of space so patients can get donors to continue donating blood while on the road. Ref. [22] claims that transportation by car offers timely and efficient emergency services for patients who could need these services, unlike other modes such as the motorcycle. Moreover, standard deliveries by car can be executed through a planned network between the healthcare facility, the patient, and the blood donor. This enhances the quality, efficiency, and cost-effectiveness of blood delivery.

Although cars are effective for transporting blood within crowded cities, it suffers significant drawbacks. Further, it is asserted that cars can be affected by jams, even when the roads are equipped, the central areas are always affected by car congestion [23]. This has a major effect on delivery efficiency. A study was taken up to determine the effects of long-distance transportation of blood tubes by car, Ref. [24] compared various delivery solutions giving an allowance of a total allowable error (TAE). The analysis used lactated dehydrogenase and potassium to determine any indications of hemolysis. The study found that the time and speed used to transport blood and blood tubes caused a significant reduction impact on the reduction of glucose levels. Approximately 5% of the total samples indicated a glucose reduction above the total accepted error. This identified the presence of hemolysis in the blood caused by vigorous movements leading to damage of cells. Although time and speed are the main factors when delivering via cars, Ref. [24] conclude that car deliveries may not be efficient if the car is at high speed.

Blood delivery vehicles should consider many factors to ensure timely and efficient delivery. A report by [25] that aimed to determine the quality of supply for healthcare products identified that blood supply within the US, and the national medical regulations by developed countries are affected by different factors. The bodies have put up several policies that must be fulfilled to fit the quality delivery of healthcare products and blood transfusions [25]. Further, it is claimed that blood deliveries should be monitored by a surveillance system that monitors and record the proper use and handling of blood components [25]. The system should also record and communicate accidents expected from the identified transportation system; this ensures a timely response and detection of adverse reactions to avoid the wastage of blood. It is further asserted that most cars used for deliveries in developed countries may not meet the desired requirements due to the costs involved making them unsuitable for blood delivery in crowded areas [26].

Another drawback of using cars to transport blood is the frequent repairs and the high maintenance costs. It has been claimed that an increase in car and truck technology is affecting car owners globally, and the rise in the cost of repairs and maintenance leads to a

rise in the price of delivering healthcare products by car [27]. Transport vehicles suffer wear and tear for every mile they cover, especially when trapped within crowded areas making them acquire additional hidden costs; fuel shortage may also affect the effectiveness of vehicle transportation. It has been claimed that the wear and tear experienced by these cars increase their chances of a breakdown during deliveries, influencing their efficiency in delivering healthcare products [28].

Apart from the expected high transportation and maintenance costs, the use of cars is affected by traffic congestion and roadblocks within crowded cities. It has been observed that the circumstances within road transportation are dynamic and fluctuate exogenously because of frequent traffic congestion, pedestrians, weather conditions as well as road visibility [28]. The study claims that issues such as road accidents increase the delay of blood deliveries by cars, affecting its cost and effectiveness. In some developed countries, traffic congestion has been found to affect donations, surgeries, and organ transplants. (Koźlak & Wach., 2018), asserts that efficient supply chain management is essential within the healthcare industry since it significantly affects primary operations. Therefore, delayed blood deliveries due to congestion could lead to patients' loss of life.

Moreover, when cars are trapped for long periods in traffic, blood quality in transit may be affected. It has been claimed that the required temperatures during transportation should be maintained at 2–6 °C; however, when the road is congested and cars cannot move, these temperatures may be altered, leading to blood degradation [21]. This primarily affects delivery cars without an efficient ATR or a Styrofoam box that regulates blood temperatures under optimal conditions. It is also claimed that increased vibrations distort various components, including the red blood cells, affecting the quality of blood.

Timely access to blood for patients requiring transfusion is the primary goal of healthcare institutions. Therefore, when the need arises for patients outside the facility, most hospitals within developed countries are forced to choose the most efficient blood delivery solution. In a study to examine the use of Motorcycle for blood and other emergency medical services in Thailand, Ref. [29] found that the delivery time by Motorlance recorded a low average activation time. The delivery mode also indicated a lower mean for the automated external defibrillator (AED), mortality rate, and response time than other delivery methods, such as the ambulance [29]. The study determined that Motorlance was an effective mode of delivery during emergencies, especially within crowded cities.

Motorbike involvement is efficient when the supply chain personnel has adopted a proper routing model within the healthcare industry. A study by [30] analyzed the possibilities of incorporating motorcycles in blood pickup and delivery services. The study proposed a mathematical model that could identify routing issues given the heterogeneous nature of the involved vehicles. The study found motorcycle inclusion attractive and efficient. Ref. [30] also indicates that the effective selection of load designs, speed, and the elimination of the routing problem of the motorbikes could lead to a significant reduction in the car travel time and distance. It is further concluded that reducing the distance covered by the blood delivery vehicle translates to the cost and time efficiency of the pickup and delivery process [31].

Adopting efficient delivery solutions is the primary concern of many healthcare institutions within developed countries. It is claimed that several land transport models, including the motorcycle, are poorly managed, making the delivery and pick-up frequency operate below the optimal levels [32]. However, based on the efficiency, speed, and timeliness associated with the emergency, motorcycles have played an essential role in delivering emergency services, including blood and other medical services. When compared to other modes, such as cars and trucks, motorcycle deliveries were found to have a smaller cost advantage [32]. Moreover, cars could be limited by congestion and traffic, but motorcycles can use the pedestrian lane during emergencies.

The COVID-19 pandemic's appearance altered how healthcare policies and operations for the conveyance of emergency services were seen. In research to determine the evolution of transportation of blood samples in developed countries, Ref. [33] claim that

most hospitals are adopting a highly diversified delivery model involving traditional and current techniques during emergencies. It is argued that motorcycle deliveries during the pandemic were widely used since it is cheaper than other transportation methods, including cars and drones [34]. Insulated boxes allow motorcycles to adhere to quality and safety by maintaining the desired temperatures in transit, preventing deterioration.

Motorcycles are flexible and can find a way in a crowded environment, making blood deliveries and other healthcare services efficient. In a study [35] to identify the effectiveness and suitability of various transport methods, the study found that motorcycles can provide reliable transportation for emergency and laboratory samples. It has been argued that delivery cars and trucks are affected by congestion; on the other hand, UAS can be affected by vibrations if delivery is a long distance [36]. Furthermore, unlike other delivery modes, a motorcycle is easy to maintain and operate. In some developed countries, such as the UK, motorbikes deliver blood samples from patients in different cities to the hospital for analysis.

Unlike other delivery modes, including cars, a motorcycle is cost-effective, making it suitable for blood deliveries. It is claimed that several hospitals require cheap delivery options; more specifically, blood needs are unpredictable; hence, deliveries can often occur within a day [37]. The effectiveness of a delivery method is based on its convenience and delivery time. It has also been known that motorcycles can carry a variety of loads while requiring minimal fuel top-up compared to cars. This motorbike characteristic ensures that blood supply is efficient and timely.

Motorcycle deliveries are influenced by various factors, including weather conditions that may hinder their operation. It is also understood that motorcycle delivery has several policies that must be fulfilled to provide an effective delivery process [38]. The motorcycle should have an insulated box and refrigerator to regulate blood temperatures, the owner or the motorcycle rider should also sign a contract with all the parties, including the healthcare facility and the patient. Moreover, all personnel operating the motorcycle at every stage of the supply chain process should undergo training on the basic procedures that may influence the proper handling of blood in transit. Many motorcycle riders may not meet these policies and regulations, making them unsuitable for blood delivery and pick-up.

Blood delivery policies and regulations, such as insulated boxes to regulate temperatures in transit, may not offer enough protection for the blood. A study (Wurbel., 2017) [35] claims that box insulation may not provide adequate insulation against external contaminants and water, rendering them incapable of maintaining contamination-free blood during transportation. Training personnel is also becoming expensive, given the increasing number of motorcycle transports within developed countries. Riding a motorcycle introduces expressive and personalized utilization of the vehicle since most users have a prevalence of high speed when riding. It has been claimed that a high motorbike rate may result in a significantly higher risk of accidents involving other road users and automobiles [39]. It has been identified that the probability of a fatal accident occurring while on a motorbike is approximately one-eighth compared to riding cars (Sham et al., 2022) [34]. Therefore, supply chain managers need to make effective decisions regarding motorcycle riders to minimize accidents during blood deliveries and pickup. Furthermore, (Sham et al., 2022) [34] assert that accidents during transit not only cause fatal injuries to the rider but cause wastage or contamination of blood which is costly given the scarce nature of blood donors.

Another critical aspect of motorcycle deliveries and pick-ups is the possibility of altering the blood conditions and components. Given the natural characteristics of blood, they must undergo as minimal vibrations as possible; however, high speed increases the chances of blood degradation. (Fujita et al., 2020) [21] asserts that frequent vibration may result in hemolysis detected by the erythrocytes leading to blood contamination; this also translates to additional expenses in finding new donors. Further analysis by [40] suggests the need for the supply chain personnel to identify the environmental characteristics of motorcycle usage to minimize potential issues arising during the delivery process. Moreover, the delivery mode transports a limited load capacity; this may increase the travel

time rendering the method inefficient when a considerable amount of blood deliveries is required within a short time.

3. Research Methodology

A preferred reporting item for systematic reviews and meta-analyses (PRISMA) was used employed for reviewing the BSC research papers for sustainable delivery. Apart from a literature review on BSC, a bibliometric review considering various analyses for citation or co-citation is also carried out [41]. Figure 2 depicts the collection of research papers as per the PRISMA methodology. The PRISMA search method was used to conduct a review of the literature [42].

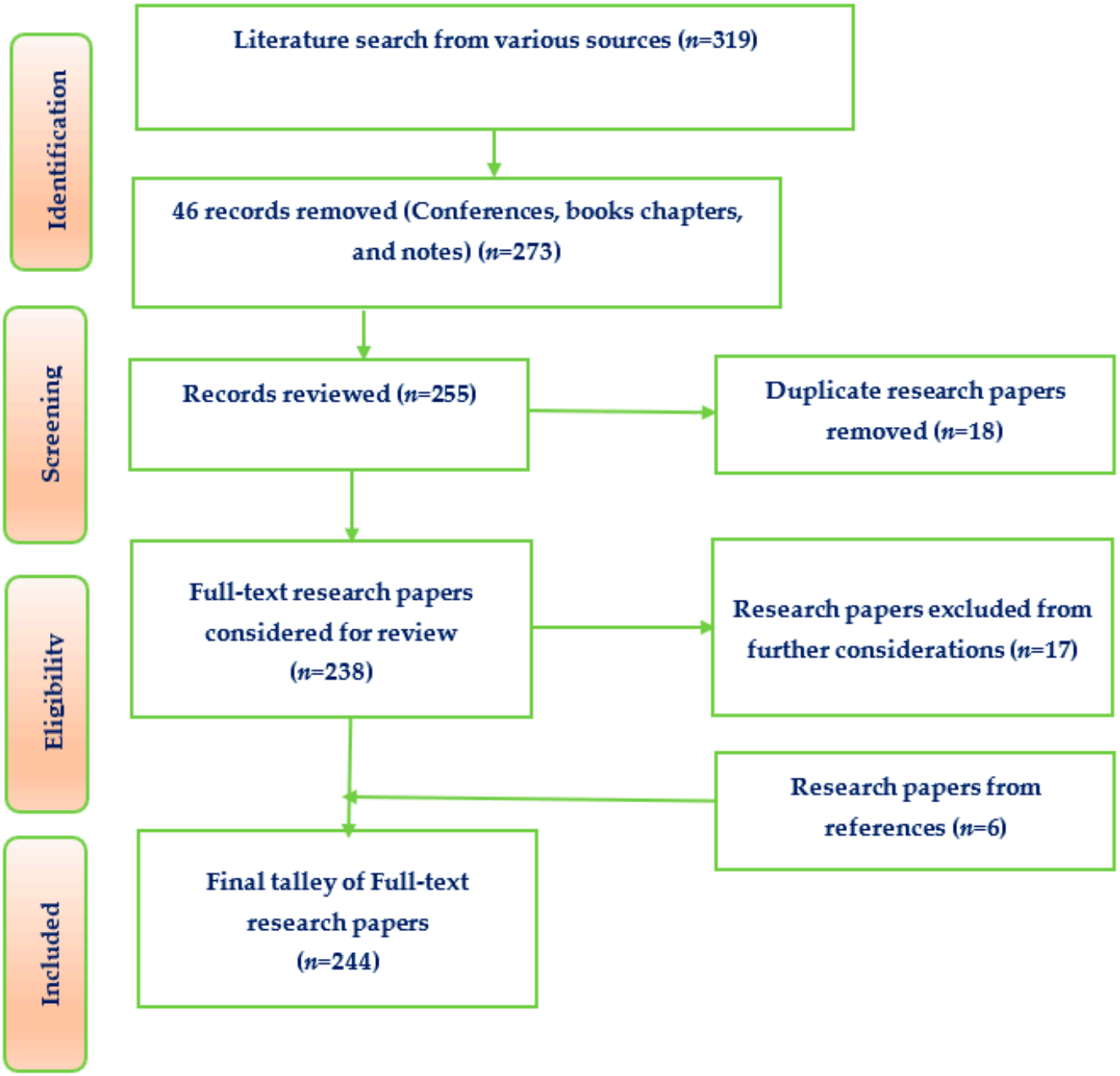

Figure 2. The PRISMA-based research methodology adopted for BSCM.

Various research papers based on BSCM were accessed from Scopus. The Scopus offers systematic access to various research papers, books, journals, conference proceedings, and lecture notes. It also offers a big collection of citations and abstracts. The various keywords "blood supply", "blood supply chain", "blood supply chain management", "blood delivery", and "sustainable blood delivery " were applied to searching the relevant BSC database.

A literature search based on blood delivery was conducted using several keywords listed in Table 1. The searched items were brought to the scope of the research by applying filters at various stages to collect the required research papers. The second filter limited the search by considering inclusive criteria of "journals & review' and excluding criteria of "conference proceedings, books, white papers, and lecture notes. The second filter brought the search items to 273 research papers by removing forty-six items from the search. The next filter was to study the duplicate records and it excluded further 18 items to yield 238 research papers. The duplicates were searched using the title of the research papers and the research paper abstract. Six research papers were left out and were readmitted to the tally of research papers for the present work by following Google Scholar and other scientific references. Thus finally 244 research papers were collected for the present bibliometric analysis.

Table 1. Search keywords.

Categories	Search Keywords
BSCM	"blood supply chain", "blood delivery", "blood bank", "blood bank management", "blood delivery management", "blood service", "blood system"
Modeling & Simulation	"blood delivery models", "blood delivery simulation", "blood delivery heuristics"
Blood-related key terms	"blood delivery collection"," blood delivery process", "blood delivery heuristics"," blood inventory management", "blood transportation management"

The Scopus search offers significant information for published research papers. The information like names of authors, author affiliation, titles of research papers, review books, notes, etc., research paper years, publishing status, publishing journals, abstracts, keywords, research funding institutions, indexing companies, etc. The collected research papers may further be analyzed using MS Excel, to provide meaningful information for its research area. Software like Biblioshiny and VOSviewer may also help in visualizing various information using research paper mapping. Bibliometric mapping offers much significant information to researchers to identify relationships concerning authors, authors' networks, authors' country citations core, keywords, etc. [43]. The VOSviewer is a tool that offers various visualization for authors, authors' networks, keywords, keyword growth, etc. to understand the research through a visualization analysis in terms of size, color, and distance to understand the research domain. Another software like Biblioshiny which employs an R-tool also offers scientific mapping in analyzing the research domain [44].

4. Results

The Scopus-based selected research papers are arranged on a yearly publication basis to understand the growth of the research domain. Various publications are investigated based on sources, publication year, publication type, etc. Much significant information for the research papers like authors, respective institutions, and respective countries are also examined.

4.1. Publication Year

Figure 3 shows the number of publications in the BSCM. It provides the number of publications per year on the *X*-axis and the number of publications on the *Y*-axis, it also shows the number of publications in each year on top of the bar. On investigating the yearly publication graph, it shows a mixed trend of increasing and decreasing numbers of publications. The year 2020 and 2022 witnessed the maximum number of publications. The number of publications was the highest during the year 2020 and dropped by 13 publications in the consecutive year and finally increased the number of research papers to 38. There is a rise in the average publications number annually which shows the growing interest in research in this domain. The trendline witnessed a mixed trend of publications with an R^2 value of 0.2393, There is no outstanding increase and decrease in the yearly publications trend hence the absence of significant linear nor an exponential increase trend is absent.

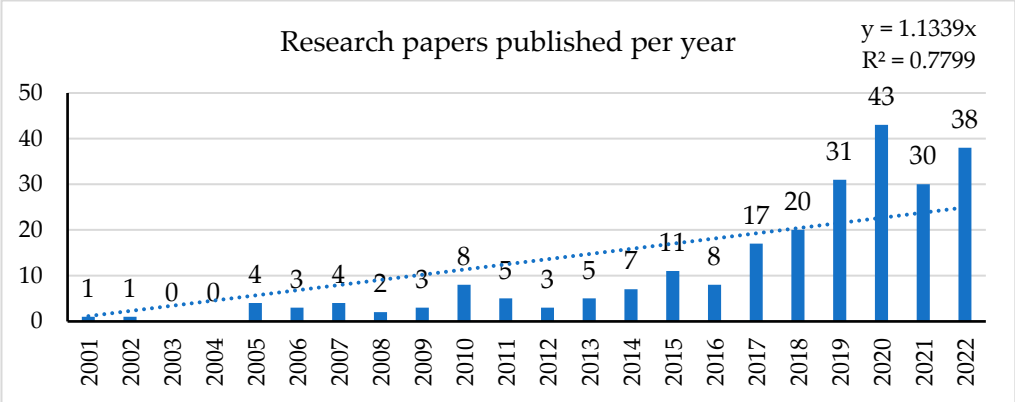

Figure 3. Research publication per year for the period 2001–2022 (30 September 2022).

Based on the yearly publications an exponentially smoothed forecast was derived considering a confidence level of 80%. Microsoft Excel may help deduce such a forecasting model as shown in Figure 4. Various forecasting accuracy measures were also calculated based on the past database using Excel to ensure the model's correctness [45]. Various accuracy measures derived are 4.87 of mean absolute scaled error (MASE), 0.4 of symmetrical mean absolute percent error (SMAPE), 8.99 of mean absolute error (MAE), and 11.68 roots mean squared error (RMSE). The timeline for the actual publication was 2001 to 2022, whereas the predicted was up to 2030. The relevant metric decides the forecasting accuracy hence a future number of publications may be known. However future publications are subject to change.

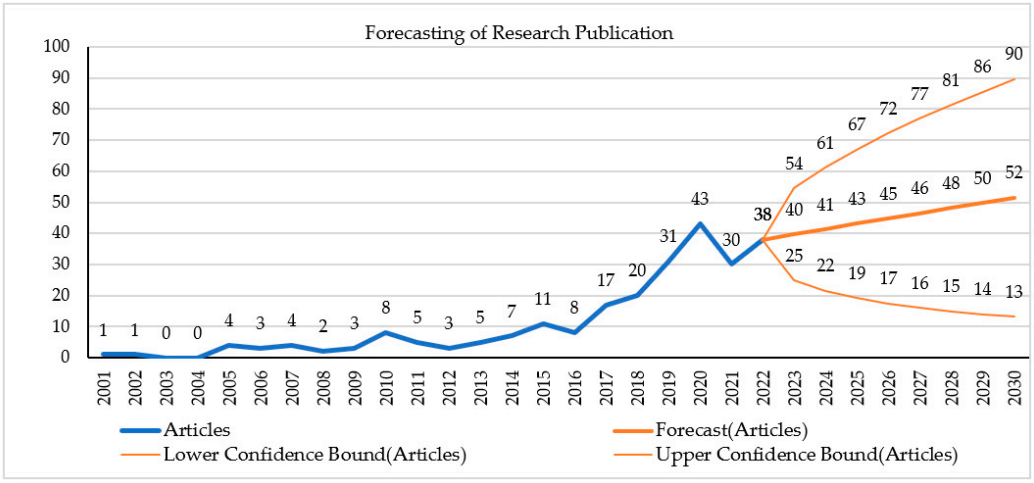

Figure 4. Forecast model for the number of publications for the decade 2021–2030.

4.2. Publication Types

The Scopus database is having various categories of research papers, reviews, conference proceedings, book chapters, and books. In the present research, only review appearing Scopus have been selected for the investigations. The systematic literature review (SLR) and bibliometric analysis help in gauging the past publications for the selected research area and lead to significant investigations leading to merits and demerits of the research papers. The review also leads to identifying the level of research carried out in the area under consideration. The review also leads to future research directions. The Scopus-based research yielded 244 research papers from 2001 to 2022 (up to 30 September 2022) and was considered for the bibliometric analysis. Out of the total 244 research papers, 237 were research papers (97.13%), and the remaining 07 research papers were review types (2.87%).

4.3. Publication Sources

The publication sources for BSCM-based research found in Scopus from 2001 to 30, September 2022 were identified and considered for analysis. Figure 5 indicates the journals publishing BSCM research papers in which the number of research publications varies from 4 to 13. The source-wise analysis shows that the journal "*Annales of Operations Research*" and "*Computers and Industrial Engineering*" published a maximum of 13 research papers on BSCM. The journal "*Transportation Research Part E: Logistics Transport Review*" published 10 and "*Socio-Economic Planning Sciences*" published 9 research papers on BSCM. "*Computers and Operations Research*" and "*International Journal of Production Economics*" published 7 research papers. "*Biomaterials*" and "*Acta Biomaterialia*" published 6 and 5 research papers respectively. "*European Journal of Operational Research*" and "*International Transactions in Operational Research*" published 4 research papers each. This shows that the blood supply chain has an increasing demand for its research.

Figure 5. Leading journals publishing research papers in the BSCM domain.

Various research based on BSCM published in various Scopus-indexed journals from 2001 to 30 September 2022 were identified and shown in Figure 5. The highest number of publications was thirteen publications. The leading five journals publishing BSCM-based research are presented in Table 2.

Table 2. Top 5 most productive journals BSCM.

Sr. No.	Journal	Publishers	No. of Publication	SCImago Journal Rank (SJR)-2021	H-Index	Subject Area and Category
1	*Annals of Operations Research*	Springer Amsterdam, The Netherlands	13	1.165	111	Business, Management and Accounting (Business, Management and Accounting (miscellaneous) (Q2)), (Strategy and Management (Q2))
2	*Computers and Industrial Engineering*	Elsevier Ltd.	13	1.775	136	Computer Science (Computer Science (miscellaneous)(Q1), Engineering (Engineering (miscellaneous) (Q1))
3	*The Transportation Research, Part E: Logistics and Transportation Review*	Elsevier Ltd.	10	2.835	122	Business, Management and Accounting (Business and International Management (Q1), Decision Sciences (Management Science and Operations Research (Q1), Engineering (Civil and Structural Engineering) (Q1), Social Sciences (Transportation)(Q1))
4	*Socio-Economic Planning Sciences*	Elsevier Ltd.	09	1.095	56	Business, Management and Accounting (Strategy and Management (Q1), Decision Sciences (Management Science and Operations Research (Q1), Statistics, Probability, and Uncertainty (Q1), Economics, Econometrics, and Finance (Economics and Econometrics (Q1), Social Sciences (Geography, Planning, and Development (Q1))
5	*Computers and Operations Research*	Emerald Group Publishing Ltd.	07	1855	160	Computer Science (Computer Science (miscellaneous) (Q1), Decision Sciences (Management Science and Operations Research) (Q1), Mathematics (Modeling and Simulation)

The BSCM growth can be gauged through the cumulative source growth. The ten publication-based cumulative growth of journal sources with the highest cumulative growth is shown in Figure 6. The source growth of the "*International Journal of Productivity and Performance Management*" journal shows the highest growth.

The *h*-index expresses the relationship of a publication with its citation impact indicating its productivity. The *h*-index may be significant in expressing the productivity of a researcher, further, it may be useful in rating the department, university, or country [46,47]. The strength of publication may also be understood from the *h*-index. Figure 7 depicts the *h*-index of the leading ten journals. The highest *h*-index found was 10 and the lowest found was 3. The "*Computers and Industrial Engineering*" had an *h*-index of 10, while "*Annals of Operations Research*" had an *h*-index of 9, and The "*Computers and Operations Research*" and "*International Journal of Production Economics*" had an *h*-index of 7. Further, the "*Transportation Research Part E: Logistics and Trans. Review*" and "*Biomaterials*" had an *h*-index of 6, "*Acta Biomaterialia*", "*Socio-Economic Planning Sciences*" had an *h*-index of 4, and "*Tissue Engineering-Part A*" had an *h*-index of 3, while "*European Journal of Operational Research*" had an *h*-index of 3.

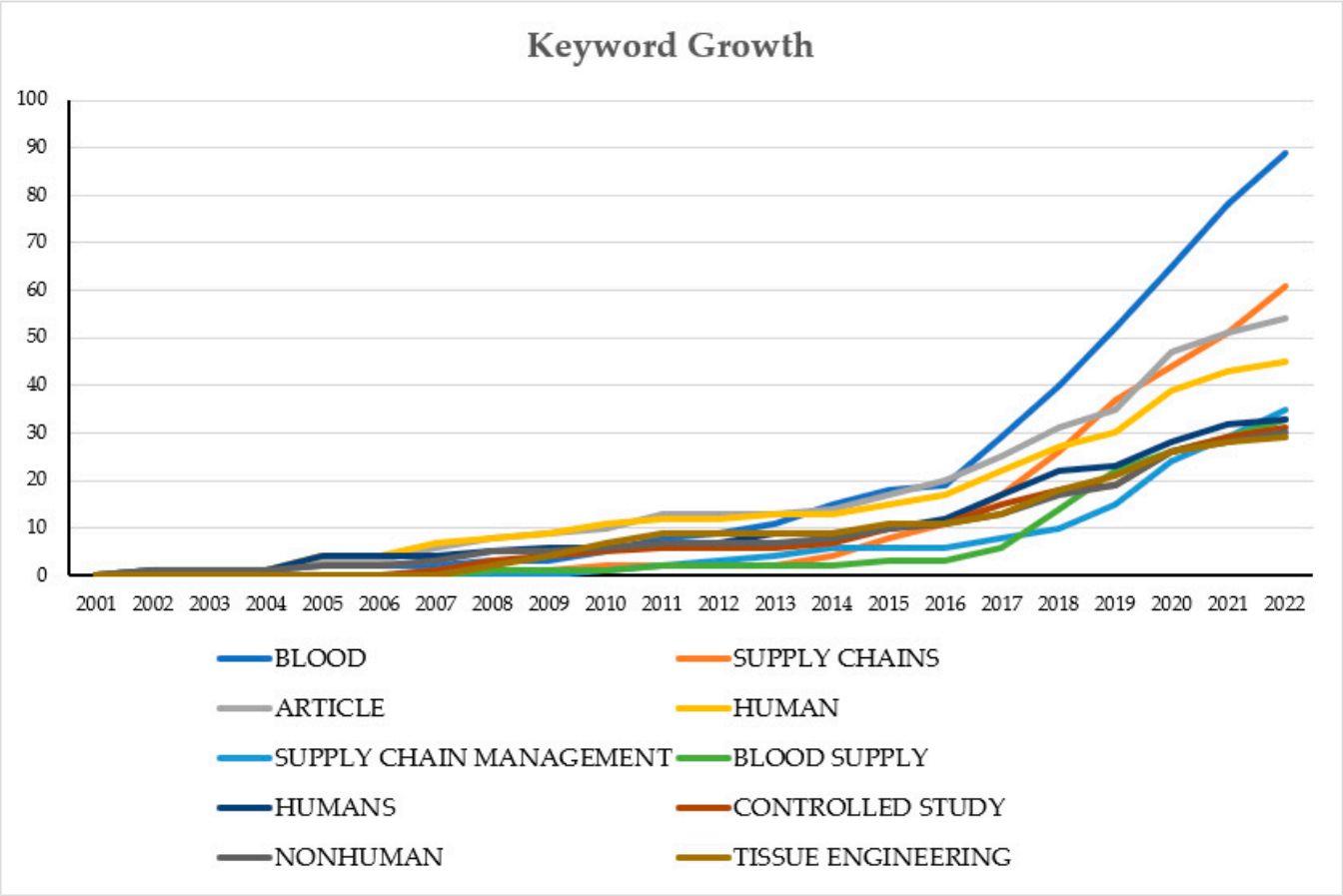

Figure 6. Source growth.

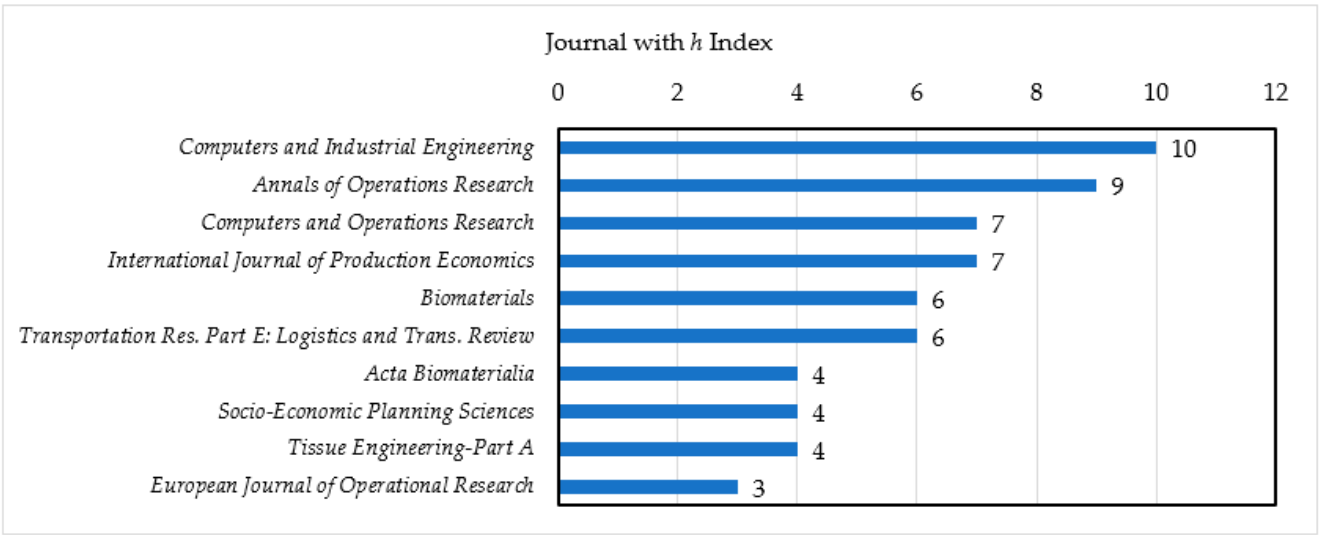

Figure 7. Publication source with *h* Index.

4.4. Countries with BSCM Publications

The country origins of BSCM-based research papers were also examined to know the leading countries in this research domain. Figure 8 shows the country analysis for BSCM-related publications. The leading countries in the BSCM were the USA (22%), China (21%), Iran (19%), the U.K.(6%), Canada (6%), South Korea (6%), Australia (5%), India (4%), Italy (4%), and Germany (4%).

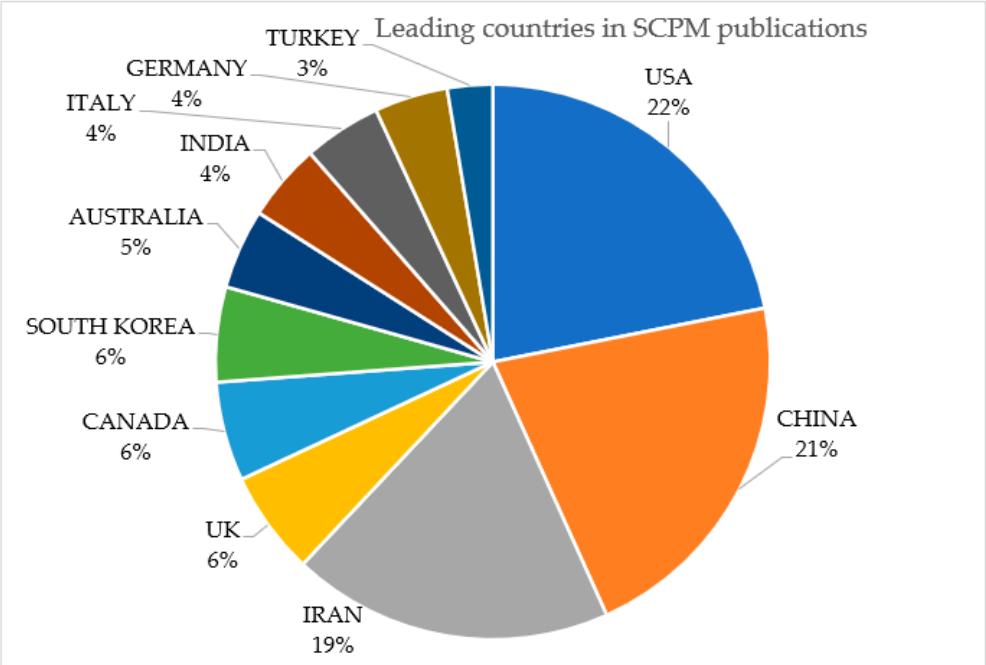

Figure 8. Leading countries in BSCM publications.

4.5. Leading Organizations and Researchers in BSCM

An analysis of the leading institutes publishing BSCM-related publications and indexed in Scopus from 2001 to 30 September 2022 has been presented in Figure 8. Iran University of Science and Technology, Iran, is in first place with 41 publications. The second place is owned by the University of Tehran, Tehran, with 23 publications, and the third place is taken by Kharazmi University, Chiang Mai University, and RMIT University, Australia, with 17 publications each (Figure 9).

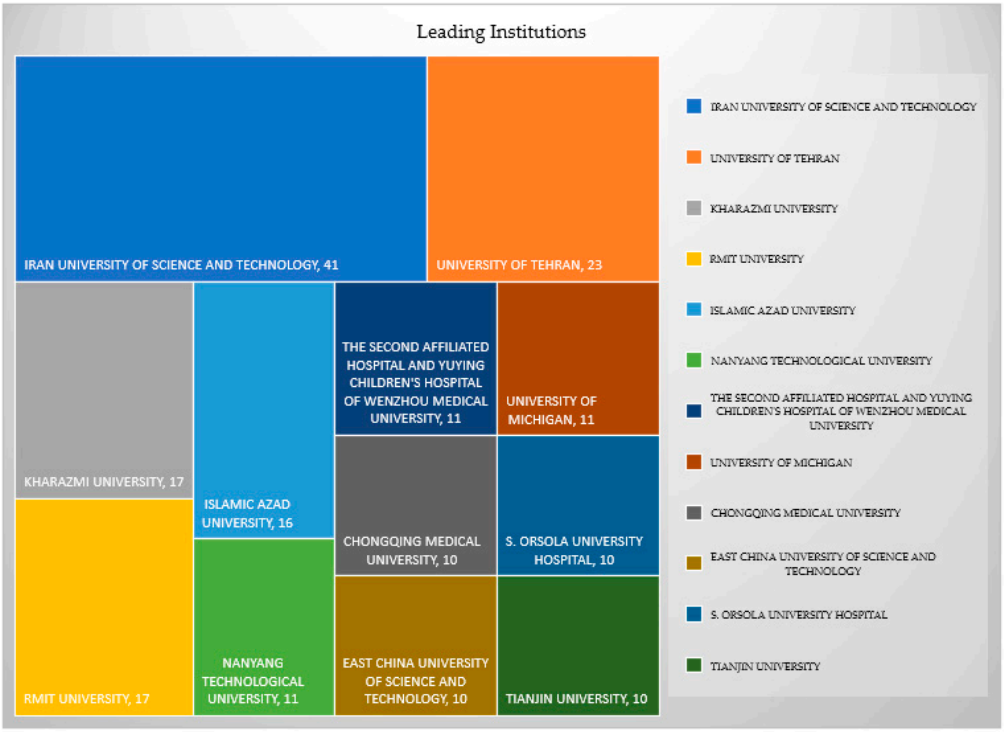

Figure 9. BSCM publications.

4.6. Citation Analysis

This section analyzes the research paper based on citation data from the Scopus database. The most cited papers are listed in Table 3. The publication titled "Supply chain management of blood products: A literature review" was published in the "*European Journal of Operational Research*" and authored by [48] and has a maximum citation of 265. The publication titled "A decision support system for demand management in healthcare supply chains considering the epidemic outbreaks: A case study of coronavirus disease 2019 (COVID-19)" by [49] was published in "*Transportation Research Part E: Logistics and Transportation Review*" and has 256 citations in second place, followed by the publication titled "Dynamic supply chain network design for the supply of blood in disasters: A robust model with a real-world application" by [50,51] published in "*Transportation Research Part E: Logistics and Transportation Review*" which has 234 citations in third place. Figure 10 shows the authors' network for BSCM. Various researchers working in the area of BSC-related domains are identified along with their network. Six large networks have been identified for the researchers working together in BSC.

Table 3. List of the most cited research paper from the Scopus database in the field of BSCM.

Authors	Title	Publication Source	No of Citation
[48]	Supply chain management of blood products: A literature review	*European Journal of Operational Research*	265
[49]	A decision support system for demand management in healthcare supply chains considering the epidemic outbreaks: A case study of coronavirus disease 2019 (COVID-19)	*Transportation Research Part E: Logistics and Transportation Review*	256
[50]	Dynamic supply chain network design for the supply of blood in disasters: A robust model with real world application	*Transportation Research Part E: Logistics and Transportation Review*	363

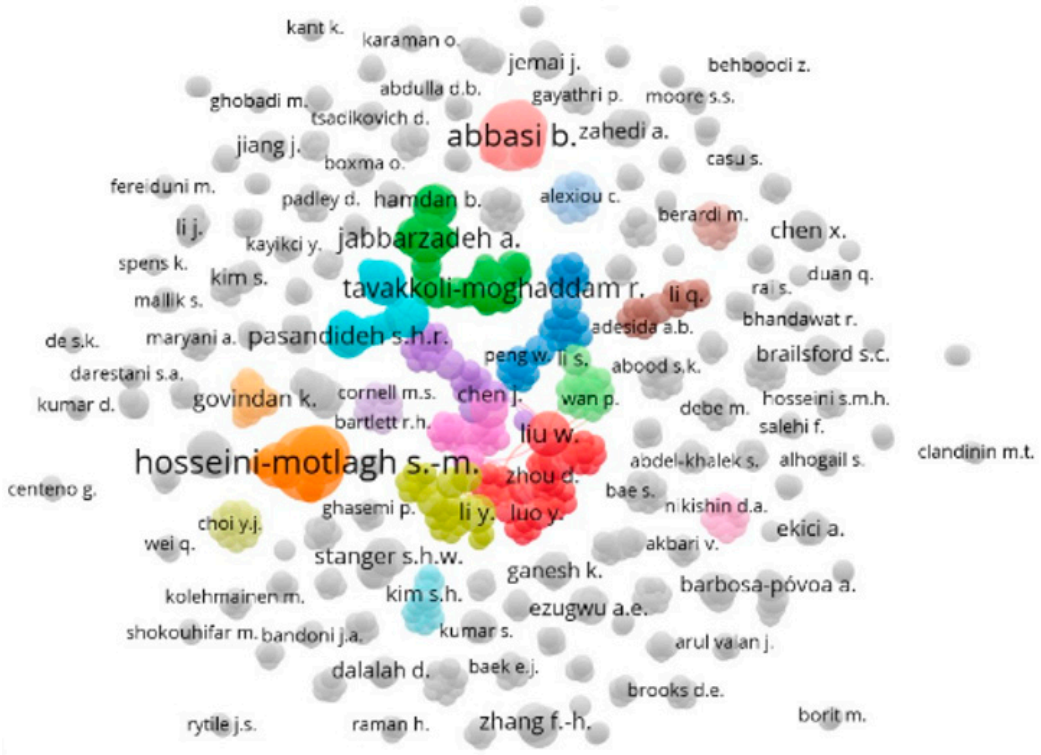

Figure 10. BSCM Authors' network.

4.7. Keyword Analysis

The keyword analysis provides information on the most frequently used keywords along with total link strength (TLS) values in BSCM-related research papers published in Scopus journals. The co-occurrence-based analysis of the technical terms that the BCSM researchers used the most in their Scopus papers. The analytical Scopus viewing barrier was set at 10 instances/keyword. Table 4 presents the top ten most frequently mentioned keywords along with their TLS values in the BSCM-related research paper indexed in the Scopus database. The first three keywords having the most occurrences were found to be "Blood Supply Chain Management", with 89 occurrences having a TLS value of 269, followed by "Blood Supply Chain" with 65 occurrences and TLS values of 238. It is followed by "Blood Supply" (TLS value 46, occurrence 175 times)".

Table 4. BSCM Keywords with the TLS values.

No.	Keyword	Occurrence	TLS
1	Blood Supply Chain Management	89	269
2	Blood Supply Chain	65	238
3	Blood Supply	46	175

The keyword growth indicates an exceeding number of research papers. The growth is depicted in Figures 11–13. The keyword "Blood" is undergone exceedingly frequent occurrences.

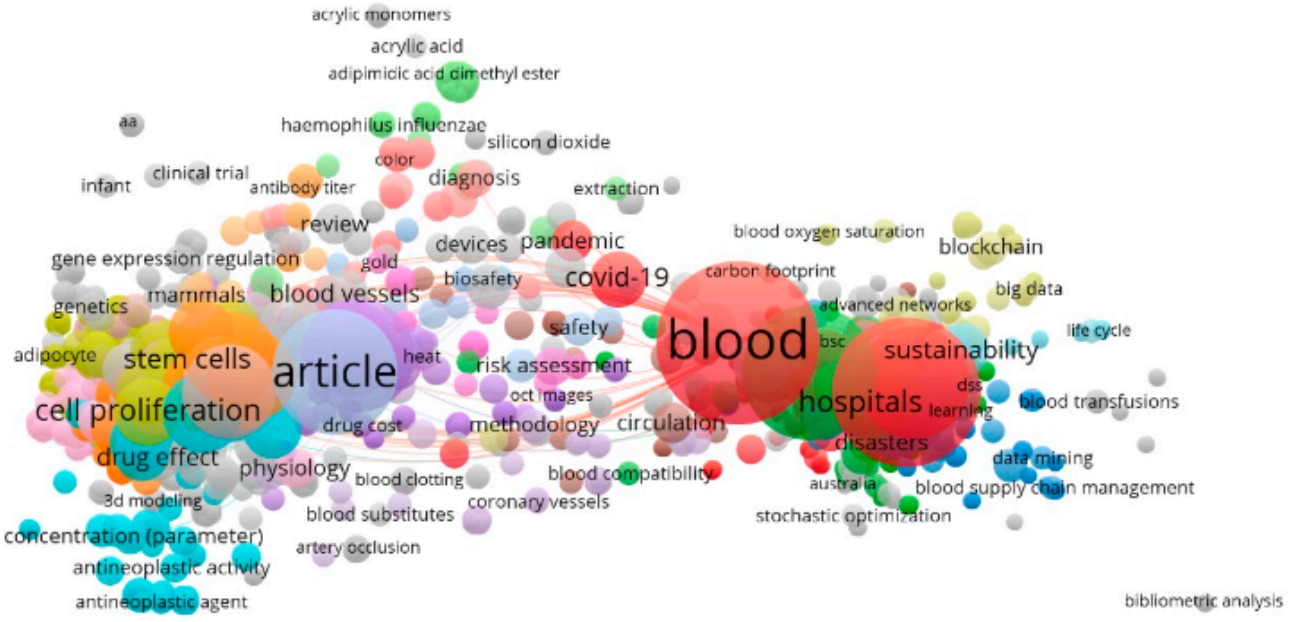

Figure 11. Keywords co-occurrence network.

Figure 12 depicts the VOSviewer-based co-authorship analysis for various Scopus-based research papers on BSCM. The analysis reveals the mutual coauthorship connections, which show the correlation between the authors.

Figure 13 depicts the cooperation network among countries represented by authors of BSCM research. The first three leading countries in BSCM-research papers publications as well as in author network corporations are India, the United States, and the United Kingdom.

The frequency with which various keywords have been used over the past five years reveals the specific fields of study. Figure 14 depicts the increase in various keywords used by writers in works on BCSM in the Scopus database between 2001 and 2022. The keywords "Supply Chain Management", "Supply chain", "Blood Supply", and "Blood" have increased gradually.

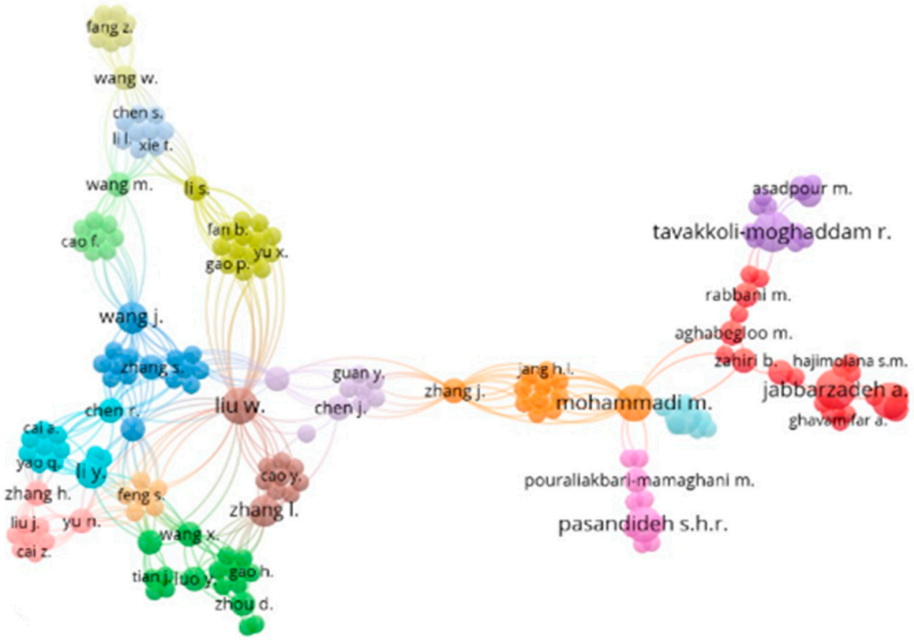

Figure 12. Cooperation network of authors of BSCM research.

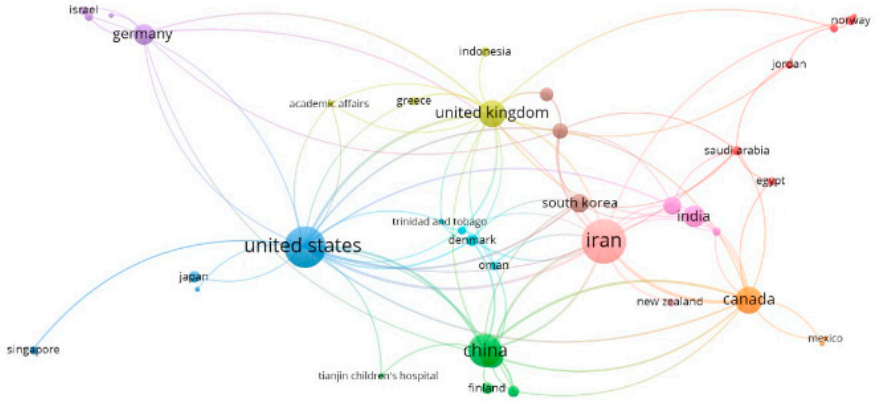

Figure 13. Cooperation network among countries represented by authors of BSCM research.

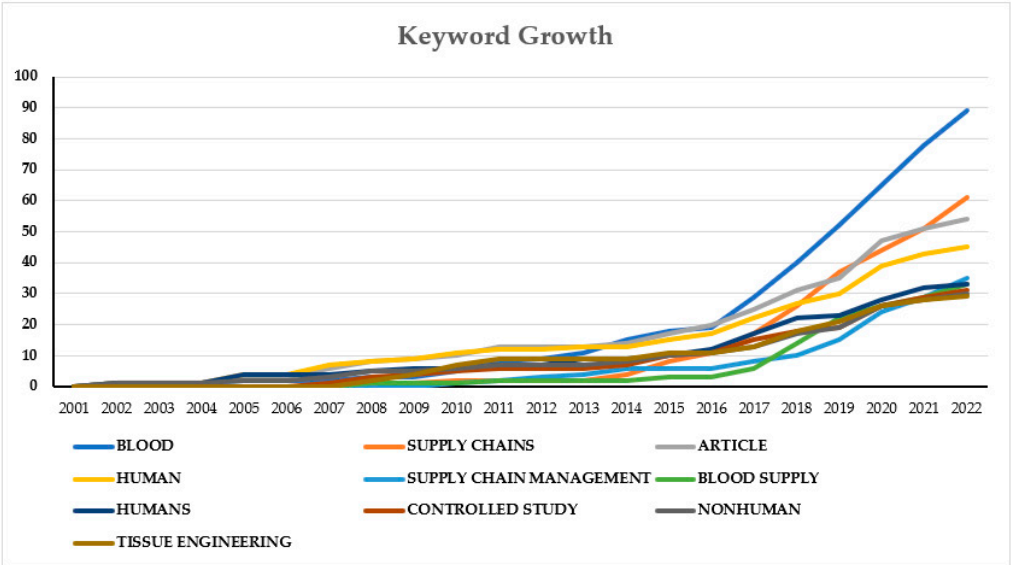

Figure 14. Keywords growth.

5. Discussion

In the healthcare industry, donated blood, with its limited life and limited resource capacity plays a crucial role in saving many lives every day. The blood delivery system is mainly serving the blood needs of donors and patients, guaranteeing the patients' needs. Since blood and blood products are scarce, the shortage and wastage may lead to an emergency. It may lead to surgery postponement, a delay in treatment, and increased waiting. Hence, the right blood delivery system must be picked for sustainable BSCM. The fast-changing lifestyle with higher mobility in higher traffic density and aging populations will surpass today's predictable blood requirements. The acute, unexpected short-term changes in blood demand and blood components necessitate the right delivery mode to fulfill the emergency [52].

The present research compares cars, motorcycles, and drones as effective and sustainable blood delivery solutions considering the blood delivery practices in many developed countries globally. It outlines the advantages and drawbacks of each delivery mode so that the quick, responsive, and cost-effective mode of blood delivery may be taken. The study has identified numerous benefits of car delivery solutions, including their efficiency in transporting all blood components compared to other methods, including the motorcycle. This ensures that there is a minimum chance of degradation during long-distance deliveries. The mode of car transportation is comparatively a cheaper transportation method, given the amount of blood that can be transported at once. Moreover, the delivery mode proved effective when the blood had to be in transit for more hours since it can sustain blood weight even during a traffic jam.

The current study compares the transportation of red blood cells (RBC) by a car while adopting three primary regulators of blood temperature-controlling toolkits during transit. Although many studies have identified that blood delivery by car has been effective, the review noted significant drawbacks of this delivery mode. Firstly, the delivery mode is affected by jams within crowded cities, the cities may be equipped with adequate transportation infrastructure, and the central areas are always affected by car congestion. The time and speed used to transport blood and blood tubes also significantly affect the reduction of the blood glucose level, which influences its efficiency and blood maintenance. Most cars used for blood deliveries within developed countries experience regular breakdowns and wear and tear, increasing the repair cost and time.

Long traffic periods also affect blood quality in transit since the required temperature is altered from the standard 2–6 °C, leading to degradation caused by increased vibrations over extended periods in transit. This increases the distortion of some components, such as the red blood cells, affecting the quality of blood. The motorcycle is also used in many developed countries; this review identifies its significant advantages, which include its ability to maneuver road congestion during emergencies. The delivery mode is more efficient when the supply chain personnel has adopted a proper routing model within the healthcare industry. A motorcycle is cost-effective, making it suitable for blood deliveries, which aligns with the objectives of many hospitals of attaining cheap delivery options.

The delivery mode of motorcycles also suffers several drawbacks. Firstly, the transport system is influenced by various factors, including weather conditions that may hinder its operation. Secondly, the delivery mode has numerous rules and regulations that need to take part in the blood delivery process. This includes the need for an insulated box and refrigerator to regulate blood temperatures; the owner or the motorcycle rider should also sign a contract with all the parties, including the healthcare facility and the patient. Another policy for motorcycle transportation is that all personnel operating the motorcycle at every stage of the supply chain process should undergo training on the basic procedures that may influence the proper handling of blood in transit. The analysis of this review indicates that blood deliveries by motorcycles are more efficient in crowded cities, especially during emergencies. Riders also tend to speed during blood delivery; therefore, high speed increases the chances of blood degradation.

The drone delivery mode is costly. The drone helps in the transportation of blood samples to complete medical diagnosis. The drone is an alternative in these situations since it can deliver more quickly than the standard method of delivery by road, which could take more time [53]. The use of Zipline's drone helped in saving African lives by delivering blood to health facilities in Rwanda quickly and safely [54]. An internal cost comparison using internal costs for various delivery modes is provided in Table 5 for internal cost comparison purposes. Blood is a fluid connective tissue that consists of plasma, blood cells, and platelets having a storage time of fewer than 6 h during the transportation of pre-processed blood between a temperature range of +20 °C to +24 °C whereas the storage time of fewer than 24 h is observed in case of the transportation of processed blood between a temperature range of +2 °C to +10 °C [55].

Table 5. Delivery mode with internal cost structure [56].

Delivery Mode	Components of Internal Costs				
	Salary	Amortization	Fuel	Maintenance and Repair	Other Operational Costs
Car	↑	↑	↑	↑	↑
Motorcycle	↑	↑	↑	↑	↑
Bicycle	↑	↑	-	↑	↑
On-foot/public transport	↑	-	-	-	-

Furthermore, complete blood count (CBC) analysis is a count of the total number of red blood cells (RBCs), white blood cells, and platelets, measurement of hemoglobin concentration, and the determination of the average size of cells and size distributions [57]. Furthermore, the storage temperature and storage time, transport position (upright, horizontal or upside-down) are some of the criteria considered for CBC analysis. Hence transportation mode for blood must be considered based on various parameters like the type of emergency, the quantity of blood to be transported, the destination from the collection center to the consumption point, etc.

There is a probability of improper handling of red blood cell transfusion or blood transportation owing to inadequate temperature control and vibration thus requisite standard operating procedures (SOPs) for rapid blood transportation. There are variations in blood storage guidelines among various countries like Japan, the US, and the UK hence systematic SOPs is warranted [19]. A blood delivery covering over 1100 km, with 23 shock events using an automobile indicated no significant difference in RBC, plasma hemoglobin levels, Na, and K when the temperature range of 4–6 °C was maintained. The hematology results, however, indicated some concerns due to vibrations and other effects [58].

6. Conclusions

Overall, blood delivery is an essential process within healthcare industries globally. This is because they contain different components with different shelf dates, requiring a reliable transport solution to ensure timely emergency response and reduce wastage. Healthcare institutions adopt several delivery modes; however, cars and motorcycles have been used over time. Deliveries by cars within developed countries are efficient for all blood components compared to other forms of transportation. It also has various advantages and disadvantages; for instance, some components, such as red blood cells, can withstand minimal vibrations, and long-hour transit can be done effectively by cars. Different studies have researched the effectiveness of transporting healthcare products and found cars to sustain more weight for long hours, especially when there is traffic congestion, as opposed to using motorcycles.

Cars also have plenty of space where patients can get transfusions while donors donate blood during emergencies in crowded cities where traffic is frequent. Some drawbacks of blood transportation by car include; unsupervised congestion within crowded cities,

possible increases in the costs of repairs, and increased car expenses increasing the costs of the blood delivery process. This renders the transport system incapable of achieving its core objective of efficiency and timely delivery of blood products.

Conversely, motorcycles have been used to supply blood products within crowded cities since they are faster and can maneuver traffic. Motorcycles for remote locations since they are flexible and can deliver all blood components. However, it can deliver a limited load capacity. This may increase the hours taken to supply the products to the designated location. Moreover, the fatal accidents caused by motorbikes during delivery affect the effectiveness of blood delivery.

The drone application in BSCM is a promising opportunity for aerial delivery during health emergencies by reducing response time and is cost-effective compared to conventional transport systems. Dron has been employed in drug delivery systems. Generally, drone delivery led to faster delivery times and less blood component wastage in health facilities. Thus the application of drones plays a significant role. However, the load-carrying capacity is low which provides a hurdle in drug delivery. Future research work may target to reduce the response time and enhance the weight-carrying capacity with optimized transportation cost.

Analyzing the present research on blood delivery, it is revealed that the temperature control for blood transfusion transportation is yet not standardized hence there is a need to establish SOPs for effective motor management. transparency. The temperature range of 2–6 °C must be adhered to keep the quality in check even if it is transported through a drone. Several protocols from European guidelines and German guidelines allowed the temperature range of 2–6 °C for 36 h and 1–10 °C for 48–60 h by keeping the ambient temperature in the range of −10–40 °C also controlling the air pressure variations and vibrationsSome protocols [58].

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