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Review

Exploring Perspectives of Blockchain Technology and Traditional Centralized Technology in Organ Donation Management: A Comprehensive Review

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Abstract: Background/Objectives: The healthcare sector is rapidly growing, aiming to promote health, provide treatment, and enhance well-being. This paper focuses on the organ donation and transplantation system, a vital aspect of healthcare. It offers a comprehensive review of challenges in global organ donation and transplantation, highlighting issues of fairness and transparency, and compares centralized architecture-based models and blockchain-based decentralized models. **Methods**: This work reviews 370 publications from 2016 to 2023 on organ donation management systems. Out of these, 85 publications met the inclusion criteria, including 67 journal articles, 2 doctoral theses, and 16 conference papers. About 50.6% of these publications focus on global challenges in the system. Additionally, 12.9% of the publications examine centralized architecture-based models, and 36.5% of the publications explore blockchain-based decentralized models. **Results**: Concerns about organ trafficking, illicit trade, system distrust, and unethical allocation are highlighted, with a lack of transparency as the primary catalyst in organ donation and transplantation. It has been observed that centralized architecture-based models use technologies such as Python, Java, SQL, and Android Technology but face data storage issues. In contrast, blockchain-based decentralized models, mainly using Ethereum and a subset on Hyperledger Fabric, benefit from decentralized data storage, ensure transparency, and address these concerns efficiently. **Conclusions**: It has been observed that blockchain technology-based models are the better option for organ donation management systems. Further, suggestions for future directions for researchers in the field of organ donation management systems have been presented.

Keywords: organ donation; organ trafficking; blockchain; smart contract; comprehensive literature review

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Citation: Bawa, G.; Singh, H.; Rani, S.; Kataria, A.; Min, H. Exploring Perspectives of Blockchain Technology and Traditional Centralized Technology in Organ Donation Management: A Comprehensive Review. *Information* **2024**, *15*, 703. https://doi.org/10.3390/info15110703

Academic Editor: Ge Yu

Received: 5 September 2024
Revised: 16 October 2024
Accepted: 20 October 2024
Published: 4 November 2024

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1. Introduction

Organ donation is one of humanity's noblest deeds, as it allows for saving lives beyond death. It provides a life-giving and life-enhancing opportunity to people who have reached the end of their road of hope. Many individuals endure the advanced stage of multiple organ failure, leaving organ transplantation as their sole recourse. Organ donation and transplantation involve surgically extracting an organ from a donor and placing it into a recipient. The most usually donated organs and tissues include the heart, lungs, kidney, liver, pancreas, intestine, cornea (eye), skin, heart valves, blood vessels, nerves, and tendons [1,2]. The key prerequisites for successful organ donation and transplantation include the organ's adequate working condition pre-implantation, donor–recipient compatibility, the donor's good health after the organ is removed, and

the patient's well-being following the successful implantation of the organ [3–5]. The first successful organ donation and transplantation occurred in 1954, when a kidney was successfully transplanted among twin brothers. Since then, the number of donations and transplantations has been steadily increasing [6,7]. The major issue of concern is that the demand for organs far outnumbers the supply. Based on the latest reports and data, an average of 17 individuals lose their lives daily while anticipating organ transplants, with a new patient being added to the waiting list every ten minutes [8–10]. There are two kinds of organ donation processes: living organ donation and deceased organ donation [11].

A flowchart of the organ donation and transplantation process is shown in Figure 1. Initially, the Hospital Transplant Team conducts a thorough examination of the donor. In the case of a deceased donor, a brain death test is performed, while for a living donor, doctors assess the donor's fitness for donation. Subsequently, all relevant medical records are submitted to the Procurement Organizer. The Procurement Organizer is tasked with evaluating the donor's condition to determine suitability for donation and ensure proper registration in the medical system. If the assessment deems the donor eligible, the Procurement Organizer forwards the data to the Organ Transplant Organizer. This stage can only proceed if the donor consents to an anonymous donation. Upon receiving the data, the Organ Transplant Organizer initiates the matching process between the donor and patients on the waiting list. This results in creating a ranked list of patients, which is then shared with Transplant Surgeons. The Transplant Surgeon, considering factors such as the donor's medical records and the prospective recipient's current health, decides whether the organ is suitable for the patient or not. When a Transplant Surgeon approves the donated organ, the Donor's Surgeon is notified to proceed with the removal process. However, in the case of a planned donation to a known person, the donor's and patient's medical reports are directly sent to the Transplant Surgeon, where the organ's suitability for the patient is based on the donor's medical records and the recipient's current health is assessed. Accordingly, the notification to remove the organ is sent to the Donor's Surgeon. In both cases, the donated organ is transported to the patient's hospital and received by the Patient's Surgeon, and the surgery for removing and transplanting the donated organ is initiated [12–14].

Several software models have been developed to streamline the intricate processes associated with the management of organ donation. These models can be broadly categorized into two groups based on the technology used and the type of database employed for storing the data. The first group encompasses models that are developed using traditional centralized technology that stores data on a single system [15,16]. Unfortunately, such models encounter several limitations, including compromised data security, and a lack of data transparency of processes for stakeholders, which further lead to issues like black market organ trading, biased organ allocation, and vulnerability to unauthorized modifications of organ waitlists. Additionally, the risk of a single point of failure also persists [17–23]. Conversely, the second group consists of models developed using the emerging blockchain-based decentralized technology, which derive various advantages from their design. These benefits include heightened data security through robust encryption, a diminished risk of single points of failure, increased user control over the data, the utilization of smart contracts for fair and unbiased operations, and the employment of consensus mechanisms for validation of transactions [24–27]. Furthermore, these models provide immutability of data and transparency of processes for stakeholders, thus resolving the issues mentioned earlier [28–34].

The work carried out in this paper provides an enhanced understanding of the system for organ donation management across various countries, thus facilitating a deeper grasp of the challenges faced in this process. Furthermore, this paper explores the models that are designed to handle these challenges, classifying them into two different categories, based on the technology used to develop the system for organ donation and the process employed for the storage of data. These categories include the models designed utilizing traditional centralized technology and the emerging blockchain-based decentralized technology. Furthermore, this survey also determines the superior choice among the two

above-mentioned models, which is a disclosure not previously noted in any prior literature review. Additionally, this review uncovers gaps in the existing work for future research directions.

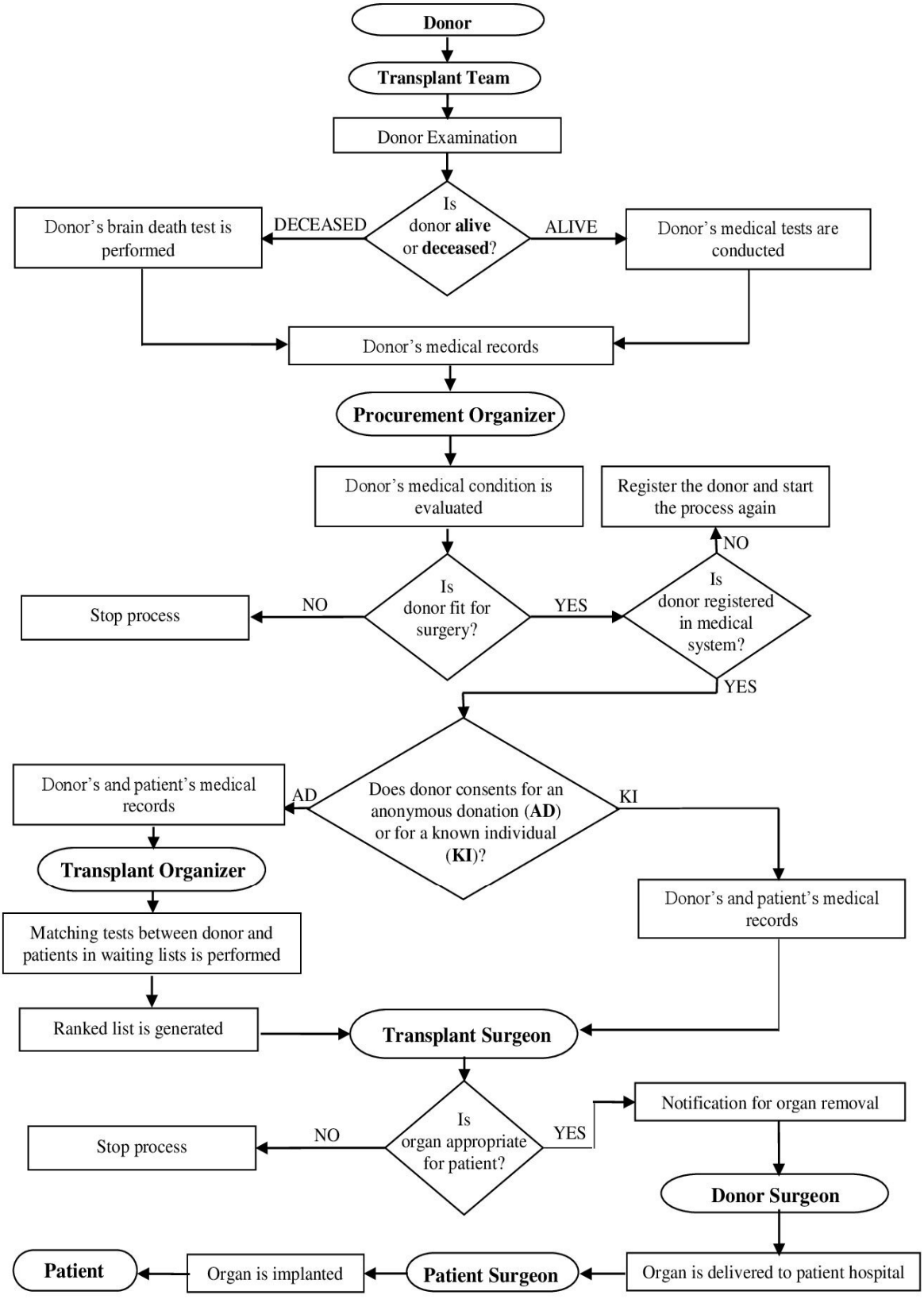


Figure 1. Organ donation and transplantation process flowchart.

1.1. Motivation Behind the Work

Organ donation serves as a source of hope for humanity, offering the gift of life to those in dire need. Managing organ donation systems relies upon diverse software models to ensure their seamless operation. Despite the implementation of such models, organ donation management systems encounter an array of challenges. Addressing these challenges is important for improvement, but it is imperative to elevate the system's functionality, security, transparency, and trustworthiness for all stakeholders involved. These aspects motivated the authors to delve into a comprehensive exploration of the global challenges confronting organ donation management systems. Moreover, analysis has shown that there is a need to scrutinize the existing landscape of software models utilized in the management of organ donation systems. Understanding these models is essential to explore which technological approaches prove more effective in meeting the complex demands of organ donation management. It can pave the way for advancements that ensure the seamless coordination of organ donation processes, ultimately saving more lives and fostering a brighter future for all. Another motivation behind this study is to explore the areas where further research and development is required.

1.2. Contribution of This Work

The key contributions of this work are outlined below:

1. A comprehensive literature review of organ donation management systems, their associated challenges, and software models designed for managing these systems, utilizing centralized technology and blockchain-based decentralized technology, has been conducted.
2. Publications from 67 journals, 2 post-doctorate dissertations, and 16 conference proceedings, published between the years 2016 and 2023, have been extracted, for review and study, using relevant keywords.
3. Based on the findings from the study, the challenges in the functioning of existing organ donation management systems in various parts of the world have been identified.
4. A taxonomy of studies based on the two above-mentioned technologies for managing organ donation systems has been presented.
5. Multiple parameters and criteria have been used to compare and analyze various organ donation management models based on the two technologies discussed above, for determining the superior among two, which is an unprecedented finding not previously documented in any prior literature review.
6. Gaps in the existing research have been identified, which provide opportunities for future research endeavors.
7. The organization of the paper is as follows: Section 2 examines the existing literature that delves into the issues of organ donation management systems and the models developed to manage these systems. Section 3 outlines the methodology for conducting this work in three phases, the Review Preparation Phase (Section 3.1), the Review Process Phase (Section 3.2), and the Review Results Phase (Section 3.3). Section 4 outlines the major gaps and possible future research directions. Finally, in Section 5, this review is concluded.

2. Analysis of Previously Published Literature

A comprehensive investigation has been undertaken to scrutinize the previously published work that delves into the issues of organ donation management systems. Additionally, this section not only encompasses an exploration of comprehensive published reviews concerning centralized models aimed at resolving pertinent issues but also explores similar work focused on blockchain-based decentralized models. The outcomes and the concise summary derived from this research have been detailed in Tables 1 and 2.

Table 1. The comparative analysis of existing literature reviews on organ donation management systems and their challenges.

Review	Year of Publication	Study Review Span	Number of Studies Reviewed	Number of Countries Surveyed	Issues Addressed											
					Organ Trafficking	Organ Black Marketing	Organ Scarcity	Supply-Demand Gap	Unethical Organ Allocation	Lack of Transparency	System Distrust	Absence of Guidelines	Tech Resource Gap	Transplant Center Networking Gap	Long Waitlists	Organ Waitlist Fatalities
Alsalem et al. [35]	2020	1985–2019	262	32												
Anselmo et al. [36]	2023	2019–2020	06	-	✓	✓			✓	✓						
Cabral et al. [37]	2018	2012–2016	14	06							✓					
Khazaee et al. [38]	2016	1990–2015	27	-			✓	✓								
Li et al. [39]	2019	1997–2018	33	07		✓			✓	✓	✓	✓	✓			
Ma et al. [40]	2021	2014–2019	06	06						✓	✓	✓	✓			
McCallum et al. [41]	2019	1997–2017	25	-												
Sharma et al. [42]	2021	1987–2018	18	07												
Silva et al. [43]	2021	1994–2019	84	15												
Skowronski et al. [44]	2021	1989–2020	45	15							✓					
Soltanisehat et al. [45]	2023	2017	02	-				✓	✓	✓		✓	✓			
This Work	-	2016–2024	43	30	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

2.1. Gap Analysis in the Existing Literature

Table 1 illustrates a comparative analysis of 11 survey papers examining the works of various authors on organ donation management systems. The following gaps have been identified:

- Very limited work concerning organ trafficking and organ scarcity within organ donation management systems has been completed.
- A few authors have shed light on the issue of black-market organ trade and discussed the disparity between organ supply and demand in their literature reviews.
- There is limited literature discussing the unethical allocation of organs, the absence of guidelines in organ donation management systems, and the technological insufficiencies.
- There is very limited work addressing the lack of transparency in processes and the distrust among stakeholders within the system.

- None of the authors have explored the interconnectivity of all hospitals through a robust communication network to facilitate recipients in finding the best-matched donors from distant locations. Additionally, none of the authors have explored papers discussing the extensive waiting list of patients for transplant procedures and the resulting fatalities due to prolonged wait times.

Table 2. The comparative analysis of existing reviews on models for the management of organ donation systems.

Review	Year of Publication	Study Review Span	Number of Studies Reviewed	Are Centralized Models for ODMS * Addressed?	Are Blockchain-Based Decentralized Models for ODMS * Addressed?	Has the Optimal Model for ODMS * Been Deliberated?
Anselmo et al. [36]	2023	2019–2020	06	No	Yes	No
Khazaee et al. [38]	2016	1990–2015	27	Yes	No	No
Niazkhani et al. [46]	2017	1990–2015	10	Yes	No	No
Sharma et al. [42]	2021	1987–2018	18	Yes	No	No
Soltanisehat et al. [45]	2023	2017	02	No	Yes	No
This Work	N/A	2017–2023	42	Yes	Yes	Yes

* ODMS—organ donation management system.

In Table 2, a comparative analysis of the existing literature evaluating different models for organ donation management systems has been presented. The following gaps have been uncovered:

- Very limited work has been completed on centralized technology-based models for organ donation management systems.
- Very few papers have been completed presenting blockchain technology-based decentralized models for managing organ donation systems.
- None of the authors have provided a unified review paper discussing both centralized and decentralized technologies.
- Additionally, none of the authors have deliberated on the superior technology for designing organ donation management systems.

2.2. Covering Gaps in This Review

The paper under scrutiny thoroughly examines organ donation management systems across 30 countries, drawing insights from the works of 43 authors. Notably, it fills significant voids by reviewing literature advocating for the interconnection of all hospitals through a robust communication network, facilitating searching for the most suitable donors irrespective of geographical boundaries. Additionally, it delves into discussions surrounding the extensive waiting lists for transplants and the resulting fatalities due to prolonged wait times, topics previously overlooked in prior surveys. Furthermore, this paper conducts an in-depth analysis of both centralized systems and blockchain-based decentralized systems within a single study. It also presents findings on the superior solution between these alternatives, a revelation absent in the existing work.

3. Methodology

The comprehensive literature review was carried out following the recommendations of various authors [47–49]. These recommendations outline a systematic approach for identifying, analyzing, and assessing the previously published work to address the research questions. The methodology applied in this survey is summarized in Table 3. In Phase 1, as outlined in Section 3.1, the review plan is established. This phase begins with acknowledging the importance of conducting a comprehensive literature review (Section 3.1.1). It also involves framing the research questions (Section 3.1.2), describing the

search string (Section 3.1.3), identifying the databases that will be explored for literature selection (Section 3.1.4), and formulating the criteria for the inclusion and exclusion of literature (Section 3.1.5). Phase 2, discussed in Section 3.2, focuses on the review process. During this phase, databases are queried to identify relevant literature (Section 3.2.1). The identified literature is then assessed based on the established inclusion and exclusion criteria (Section 3.2.2), followed by a thorough evaluation of the selected literature (Section 3.2.3). Finally, Phase 3, covered in Section 3.3, involves the collection and compilation of the literature. The literature collected is organized to address different research questions, specifically, RQ1 (Section 3.3.1), RQ2 (Section 3.3.2), and RQ3 (Section 3.3.3). This ensures a structured compilation of information relevant to the research questions.

Table 3. The methodology applied in this review work.

Phase	Process	Accomplishments
Phase 1 (Section 3.1)	Review plan	• Acknowledge the significance of a comprehensive literature review (Section 3.1.1) • Frame research questions (Section 3.1.2) • Describe the search string (Section 3.1.3) • Identify databases to be explored for the selection of literature (Section 3.1.4) • Formulate criteria for inclusion and exclusion of literature (Section 3.1.5)
Phase 2 (Section 3.2)	Review process	• Query databases to identify literature (Section 3.2.1) • Assess literature based on criteria for inclusion and exclusion (Section 3.2.2) • Selected literature assessment (Section 3.2.3)
Phase 3 (Section 3.3)	Literature Collection and Compilation	• Compilation of literature collected to address RQ1 (Section 3.3.1) • Compilation of literature collected to address RQ2 (Section 3.3.2) • Compilation of literature collected to address RQ3 (Section 3.3.3)

3.1. Phase 1: Review Plan

3.1.1. The Significance of a Comprehensive Review

Organ donation and transplantation, a vital component of the healthcare industry, bestows numerous advantages upon humanity. It is imperative to conduct an exhaustive examination of this sector, identifying the challenges encountered in the global organ donation management system. Furthermore, it is essential to scrutinize all the existing models designed for managing the system to ascertain their strengths and weaknesses, fostering future enhancements, research, and innovations, as well as the identification of superior models.

3.1.2. Research Questions

This comprehensive literature review will concentrate on four research questions (RQs), as mentioned in Table 4:

3.1.3. Search String

A search string is essential to find relevant articles on different search platforms that can respond to the research questions. First, the main search phrases arising from the research questions were identified. Then, using the OR operator, these core search phrases were connected to a list of their synonyms and alternatives. Finally, the AND operator was used to combine all of the major search phrases. The result of this procedure is the search string that follows, which is subsequently used to query various databases.

((“organ” or “human organ”) AND (“donor” OR “donation” OR “transplant” OR “transplantation” OR “waitlist”) AND (challenges OR issues OR trafficking OR “black market”)) OR ((“organ donation” OR “organ transplantation” OR “organ donation management”) AND (“blockchain” OR “smart contract” OR “dApp” OR “model” OR “system”))

Table 4. Research questions for a comprehensive review.

Research Question	Motivation
RQ1: What are the global challenges confronting organ donation management systems?	• To explore issues in organ donation management systems worldwide. • To find efficient solutions for resolving the issues.
RQ2: What centralized technology-based models have been developed to address the challenges in organ donation management systems?	• To identify the centralized technology-based models that have been developed for the management of organ donation systems. • To identify the capability of these models in resolving the issues confronting organ donation management systems. • To identify the technology and tools that are used to develop these models.
RQ3: What blockchain-based decentralized models have been developed to address the issues in organ donation management systems?	• To identify the blockchain technology-based models that have been developed for the management of organ donation systems. • To identify the capability of these models in resolving the issues confronting organ donation management systems. • To identify the type of blockchain used to develop these models.
RQ4: Which among the two available models for handling the challenges in the organ donation management systems proves to be superior?	• To uncover superior technology among centralized models and blockchain-based decentralized models for managing organ donation systems. • To guide future research and innovations.

3.1.4. Databases Explored for Retrieving Relevant Literature

To obtain all the publications relevant to the research questions, mentioned in Section 3.1.2, the appropriate digital sources must be selected. In this context, databases that are well-regarded within the research community for conducting surveys and comprehensive literature reviews have been opted for. Furthermore, post-doctorate dissertations have also been reviewed to uncover effective solutions to the research questions. The selected digital search resources to explore publications and post-doctorate dissertations are outlined in Table 5:

Table 5. Selected digital search resources (sorted alphabetically).

Digital Resource	Link
Publications in Journals and Conferences	
ACM	"www.acm.org/dl (accessed on 03 April 2024)"
Elsevier	"https://www.sciencedirect.com/ (accessed on 12 April 2024)"
Google Scholar	"www.scholar.google.co.in (accessed on 20 April 2024)"
IEEE Xplore	"ieeexplore.ieee.org (accessed on 04 May 2024)"
Inderscience	"https://www.inderscienceonline.com/action/doSearch (accessed on 15 May 2024)"
ResearchGate	"https://www.researchgate.net/ (accessed on 22 May 2024)"
Springer	"https://www.springer.com/in (accessed on 06 June 2024)"
Taylor and Francis	"https://www.tandfonline.com/search/advanced (accessed on 10 June 2024)"
Wiley	"https://onlinelibrary.wiley.com/ (accessed on 17 June 2024)"
Post-Doctorate Dissertations	
ProQuest	"www.proquest.com (accessed on 26 June 2024)"
EBSCO	"www.ebsco.com (accessed on 04 July 2024)"
ORA	"ora.ox.ac.uk (accessed on 11 July 2024)"
ShodhGanga	"https://shodhganga.inflibnet.ac.in/ (accessed on 17 July 2024)"

3.1.5. Criteria for Inclusion and Exclusion of Literature Retrieved

The inclusion and exclusion criteria specify the conditions under which a publication meets the requirements for the extraction of relevant data. It also specifies the conditions under which a publication may be excluded from consideration within the literature review. Based on the requirements of the RQs, Table 6 illustrates the criteria for the inclusion and exclusion of publications from the literature review process.

Table 6. Inclusion and Exclusion Criteria.

	Exclusion Criteria
i.	Publications on organ preservation
ii.	Publications on organ chip
iii.	Publications on organ-on-a-chip
iv.	Publications on artificial organ
v.	Duplicate publications repeated in different resources
vi.	Publications published before 2016
	Inclusion Criteria
i.	Publications on organ donation issues
ii.	Publications on transplantation issues
iii.	Publications on the organ donation management systems
iv.	Publications from journals, conferences, and doctorate thesis
v.	Publications published in the English language
vi.	Publications published between 2016 and 2023

3.2. Phase 2: Review Process

3.2.1. Literature Identification

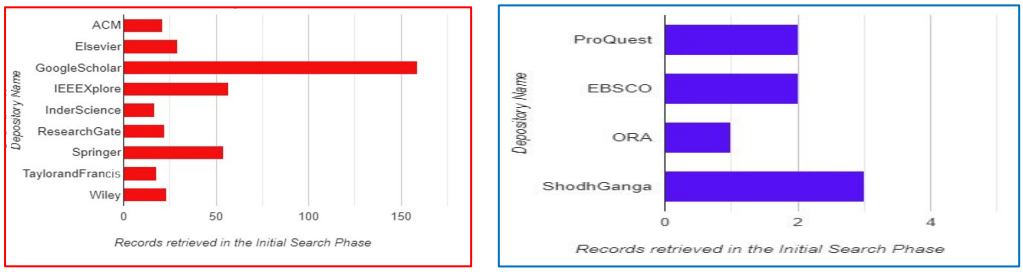
The relevant literature used to answer the research questions, mentioned in Section 3.1.2, is searched from the digital databases, mentioned in Section 3.1.5, using the search string, mentioned in Section 3.1.4. In the initial search phase, a total of 370 publications and post-doctorate dissertations have been identified from different digital resources, based on the search string, as shown in Table 7. Among these, 223 journal publications, 126 conference proceeding publications, and 21 post-doctorate dissertations have been explored. Figure 2 presents a bar chart displaying the number of publications explored during the initial search phase across various digital repositories. Figure 3 represents a pie chart illustrating the categories of publications explored, encompassing journal publications, conference proceedings, and post-doctoral dissertations.

Table 7. Publication search results from different digital databases.

Resource Name	**Total Records Found in Initial Search Phase (Section 3.2.1)**	**Records Found When Exclusion Criteria Are Applied (Section 3.2.2)**	**Records Found When Inclusion Criteria Are Applied (Section 3.2.2)**
Publications in Journals and Conferences			
ACM	21	9	2
Elsevier	29	5	4
Google Scholar	159	54	40
IEEE Xplore	57	21	11
InderScience	17	7	1
ResearchGate	22	5	3

Table 7. *Cont.*

Resource Name	Total Records Found in Initial Search Phase (Section 3.2.1)	Records Found When Exclusion Criteria Are Applied (Section 3.2.2)	Records Found When Inclusion Criteria Are Applied (Section 3.2.2)
Springer	54	8	16
Taylor and Francis	18	3	2
Wiley	23	4	4
Post-Doctorate Dissertations			
ProQuest	2	1	-
EBSCO	2	-	-
ORA	1	-	-
ShodhGanga	3	2	2
Total	370	139	85



(**a**) (**b**)

Figure 2. Publication search results in the initial search phase. (**a**) Journal and Conference Publications; (**b**) Post-Doctorate Dissertations.

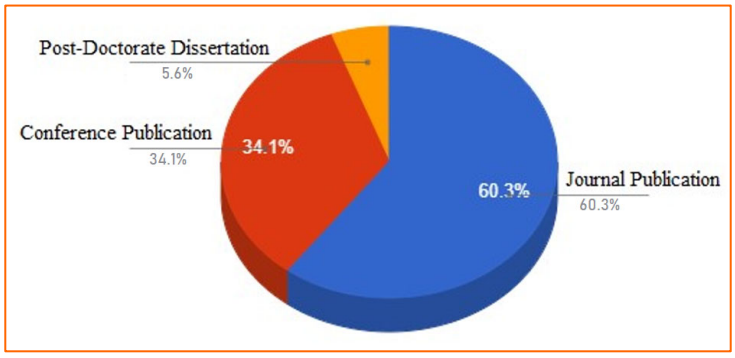
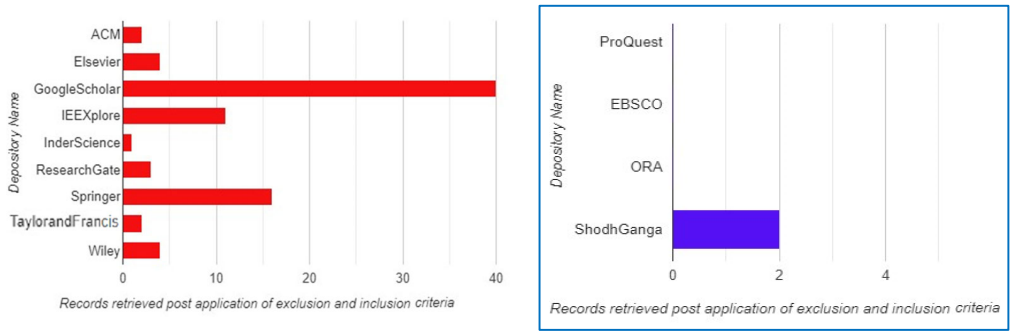


Figure 3. Types of publications explored in the initial search phase.

3.2.2. Literature Assessment Based on Exclusion and Inclusion Criteria

After applying the exclusion criteria, mentioned in Table 6 of Section 3.1.5, 139 publications were selected for the next search phase. After applying the inclusion criteria, stated in Table 6 of Section 3.1.5, to these 139 publications, 85 publications were finally selected for the comprehensive literature review, as mentioned in Table 7. Among these, 67 journal publications, 16 conference proceeding publications, and 2 post-doctorate dissertations have been selected. Figure 4 shows a bar chart indicating the count of publications chosen following the application of exclusion and inclusion criteria from diverse digital repositories. Figure 5 represents a pie chart depicting the selected publication types, which include journal publications, conference proceedings, and post-doctoral dissertations, after applying exclusion and inclusion criteria to the publications initially identified.



(**a**) (**b**)

Figure 4. Publication search results after the application of exclusion and inclusion criteria. (**a**) Journal Publications and Conference Publications; (**b**) Post-Doctorate Dissertations.

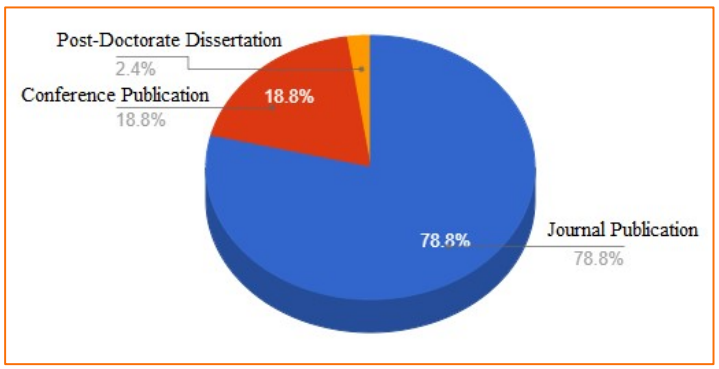


Figure 5. Types of publications explored after the application of exclusion and inclusion criteria.

3.2.3. Selected Literature Assessment

The selected literature would contribute to the investigation of research questions RQ1, RQ2, and RQ3, as mentioned in Section 3.1.2. The exploration of research question RQ4 will be based on a thorough analysis of the findings from RQ2 and RQ3. Table 8 highlights the year-wise total number of publications selected to address research questions RQ1, RQ2, and RQ3. Figure 6 illustrates the total number of publications selected for the comprehensive literature review, categorized by the year of publication. Figure 7 demonstrates the cumulative publications selected annually to address research questions RQ1, RQ2, and RQ3. Figure 8 illustrates the complete Review Process Phase.

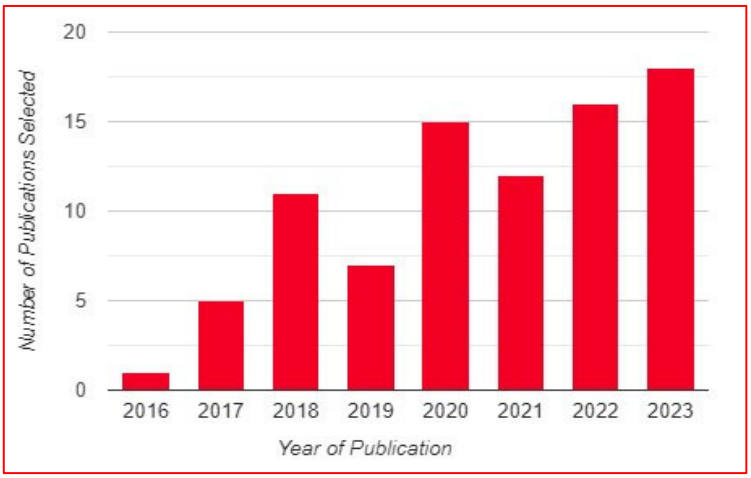


Figure 6. Year-wise publications selected.

Table 8. Year-wise selection of publications for addressing RQ1, RQ2, and RQ3.

Year of Publication	Number of Publications Selected for Addressing Research Question RQ			Total
	RQ1	RQ2	RQ3	
2016	0	1	0	1
2017	4	1	0	5
2018	9	1	1	11
2019	2	1	4	7
2020	9	1	5	15
2021	9	1	2	12
2022	9	3	4	16
2023	1	2	15	18
Total	43	11	31	85

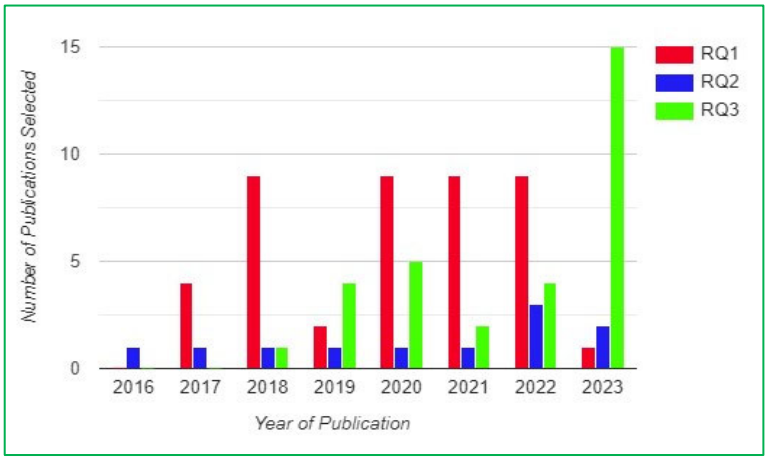


Figure 7. Year-wise publications selected to address RQ1, RQ2, and RQ3.

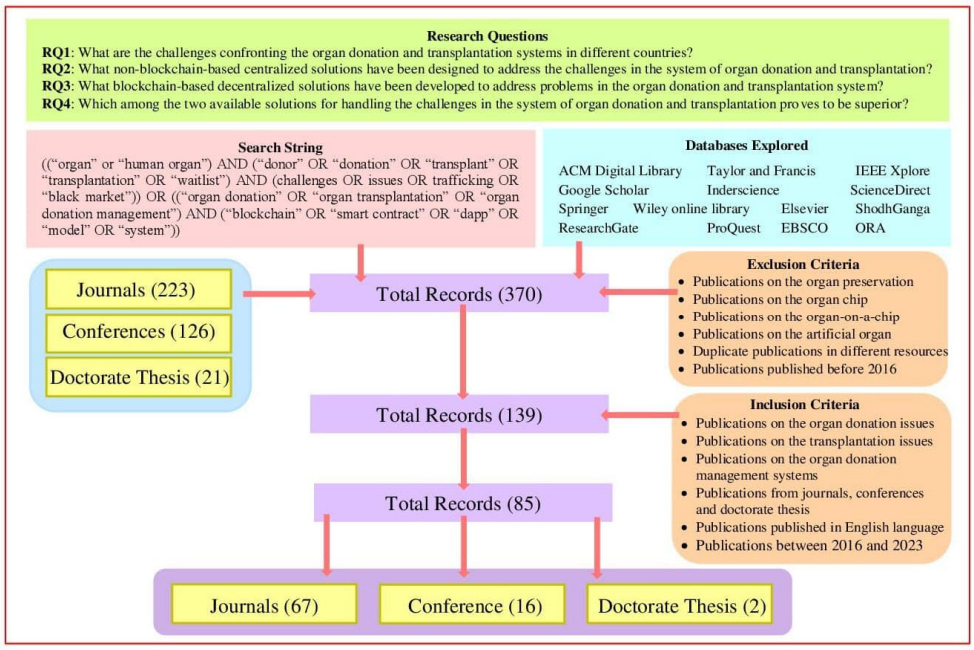


Figure 8. The Review Process Phase.

3.3. Phase 3: Literature Collection and Compilation

This section addresses the research questions framed in the preceding section. To answer the research questions, 85 publications have been selected, out of which 67 are published in journals, 16 in conference proceedings, and 2 as post-doctorate dissertations.

3.3.1. The Literature Collected to Address Research Question RQ1

This section compiles and briefs the organ donation management systems of 30 countries, selected randomly, by reviewing 43 publications from journals, conferences, and post-doctorate dissertations, published between 2017 and 2023, to provide an answer to the research question RQ1. Table 9 lists the countries whose organ donation management systems have been reviewed, and Figure 9 shows the number of studies reviewed by publication year. Figure 10 depicts a map indicating the nations whose publications have been explored to examine and analyze concerns in their respective organ donation management systems. Figure 11 illustrates the timeline of the publications that have been reviewed to address RQ1.

Table 9. Organ donation systems reviewed by country.

Continent	Country
Africa	Egypt [50] Nigeria [51] South Africa [52,53]
Antarctica	-
Asia	Bangladesh [54] China [55,56] Egypt [50] India [57–60] Indonesia [61] Iran [62] Israel [63] Korea [64] Malaysia [65] Nepal [66,67] Pakistan [68] Qatar [69]
Australia	Australia [70]
Europe	Belgium [71] France [72] The Netherlands [73] Serbia [74] Slovenia [75] Spain [72] Turkey [76]
North America	America [77]
South America	Brazil [78]

According to Columb [50], the underground market for transplantable organs is developing and multiplying in Egypt as a result of the growing paucity of transplantable organs. All organ trading trials in Egypt prove that legitimate organizations such as hospitals, blood banks, and clinics, as well as their employees, are directly or indirectly involved in facilitating illegal transplants. The major catalyst behind these illegal operations is the lack of transparency in the organ donation management system of the country. Obani and Okunrobo [51] discuss the huge gap between the supply of organs and its demand in Nigeria. The authors calculate that 125,000 persons in Nigeria undergo organ transplantation each year. However, when compared to the number of people on organ

waiting lists, this figure is quite small. This raises the prospect of illicit actions such as human organ trafficking and the trafficking of humans for organ extraction. Furthermore, rising demand for human organs has the potential to raise profits in this market, hastening Nigeria's organ black market. Iroanya [52] addresses human and organ trafficking in Africa. The main purpose of human trafficking in Africa is to unlawfully take their organs and sell them on the black market for money. The lack of norms and regulations in the region is to blame for this illegal behavior. The lack of criminal traceability and tractability features in the country's organ donation management system hastens the problem. Yesufu [53] discusses the problem of organ trafficking in South Africa, claiming that the trafficking of human organs, termed "Transplant Tourism," has become a lucrative business in the country. The primary driving force behind these illicit activities stems from the opacity within the country's organ donation management system.

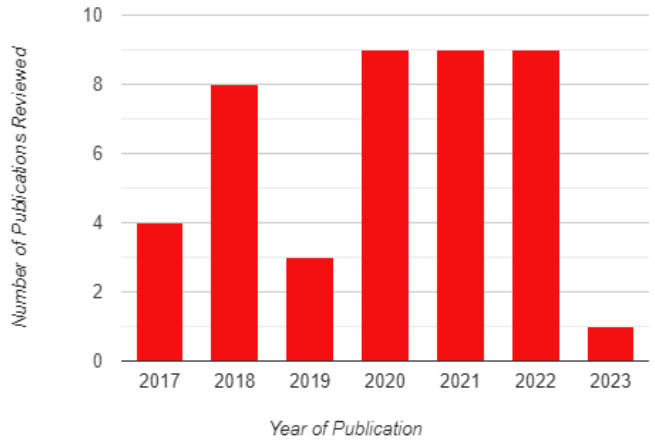


Figure 9. Distribution of publications on organ donation issues by year.

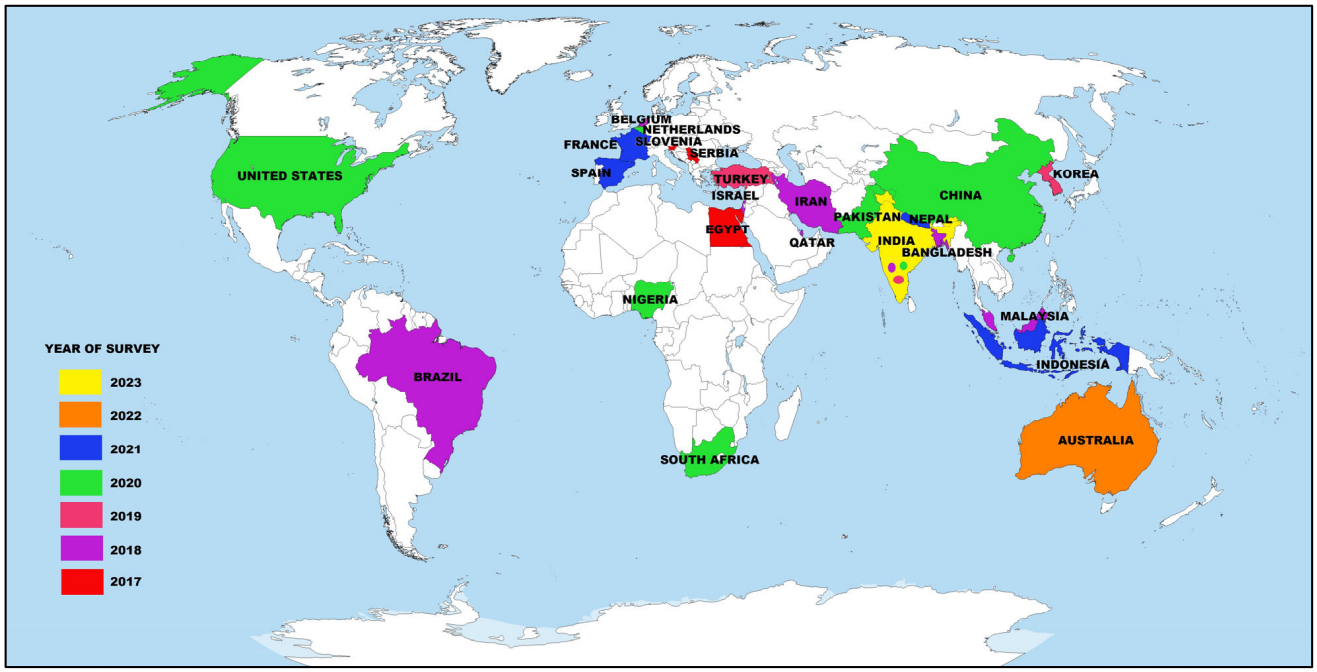


Figure 10. A chronological display of countries investigated to analyze issues in their organ donation systems.

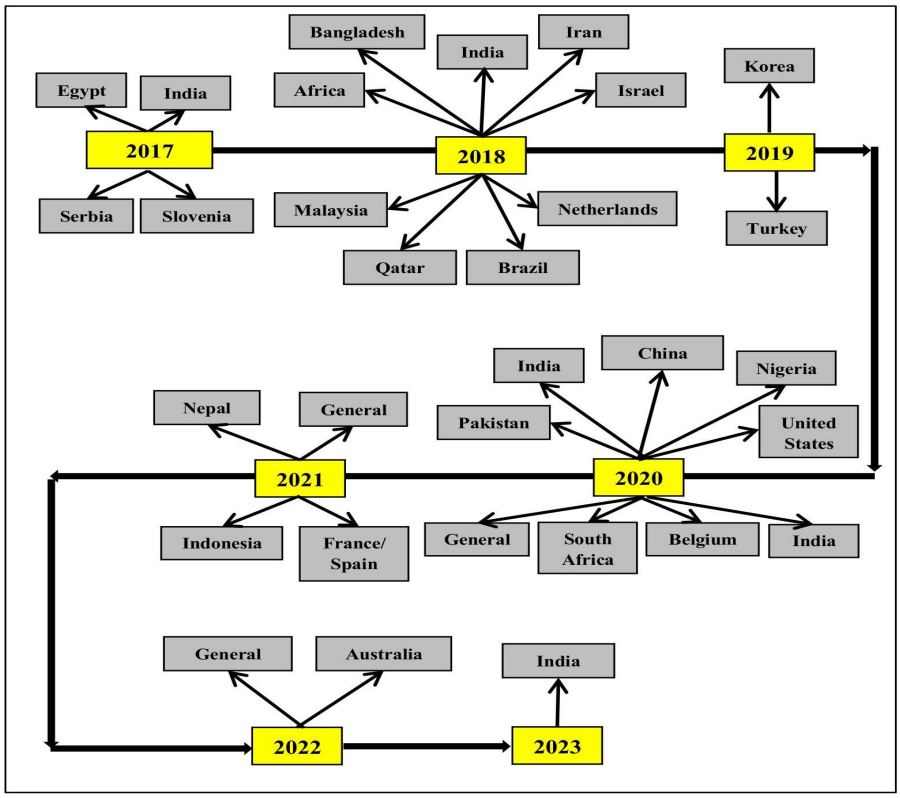


Figure 11. A timeline of the publications that have been reviewed to address RQ1 [50–92].

Moniruzzaman [54] investigates the illicit market in Bangladesh. Organ transplantation has spawned an unlawful thriving commerce in organs drawn from the living bodies of Bangladesh's desperately poor. This organ trade causes cruelty, mistreatment, and suffering among the poorer sections of society who sell their live organs on the underground market. The author suggests that the system of organ donation management should be ethically transparent for stakeholders. Shi et al. [55,56] conducted research on China's organ donation management systems. The authors draw attention to China's dominance in liver transplants among Asian countries, attributed to a controversial nexus between the legal system and organizations that procure organs. This connection has increased worries about trafficking, illegal organ markets, and abuses of human rights. Alarms are also raised by unethical organ donors, which occasionally involve political organizations. Despite the Indian government's implementation of various policies and acts, such as the Transplantation of Human Organ and Tissue Act in 1994 (subsequently improved in 2014 and 2017), Sachdeva [57] discovers that organ trafficking and the illicit organ trade persist in India, tarnishing the country's global reputation. Additionally, the authors state that there is a huge imbalance between the number of people in need of organs and the available donor pool in India. This problem is worsened by a lack of attentiveness and poor inter-hospital communication in the organ donation management system, which prevents consenting persons and deceased family members from donating organs.

Nallusamy [58] addresses the current state of the organ donation management system in India, where the lack of organ donors as well as medical and financial obstacles make it difficult to perform organ transplants. Additionally, there is a lack of a centralized organ-sharing network across hospitals in India that would allow for the maintenance of a registry of organ donors and recipients to ensure that the greatest number of organs is used as effectively as possible and that organ donation is fair and equitable. Despite ongoing attempts to encourage deceased organ donation, Saxena et al. [59] note that India still faces a significant organ supply and demand gap. The major catalyst behind this is citizens' lack of confidence in the impartiality of the organ donation management

system, which further affects the number of organ donations in the country. According to Mukherjee et al. [60], India passed "The Transplantation of Human Organs and Tissues Act, 1994" in 1994 to allow for the transplantation of human organs. Despite the stringent laws and regulations, organ trafficking is occurring on a massive scale. According to the authors, improvements in the country's organ donation management system are required to prevent the commercial exploitation of donated organs. According to Yanto et al. [61], the development of Indonesia's legal framework for organ donation management has not kept pace with technological advancements. The system lacks laws and regulations to prevent doctors and other medical professionals from taking part in the illegal trade in human organs.

According to Kiani et al. [62], Iran is also experiencing problems with the organ donation management system including a lack of technical facilities in hospitals, difficulty in accessing transplant services, and a lack of integration of its numerous separate transplant institutions. Another study by Berzon [63] reveals that because of the lack of a transparent management system in Israel, transplant tourism and the underground market of organs are increasing rapidly. Cho [64] discusses organ commercialism and the immature organ donation management system in Korea. The lack of clear legislation and regulations governing organ donation in Korea is a problem. There is mistrust among Koreans in the procedures for allocating organs, including worries about their organs being sold on the illicit market and the mechanisms favoring the wealthy and famous. The system's lack of openness is the main cause of the lack of trust. Organ trafficking in Malaysia has been a topic of discussion for many years, according to Zulaikha et al.'s [65] analysis. Organ trafficking and exploitation of the victims, resulting from a lack of transparency of processes for the stakeholders, are the major issues in the country's donation management systems. According to studies by the WHO, 10 percent of the kidneys that are transplanted each year are obtained from Malaysia's underground market. Thapa [66] discusses the problem of illicit organ transplantation in Nepal, where organ traffickers easily target the country's poorest residents to sell their organs, particularly kidneys. The root cause of this unlawful practice stems from the nation's pervasive poverty and the inadequate transparency surrounding the processes within the country's organ donation management system, which fails to adequately engage stakeholders. Additionally, Gawronska [67] completed a case study on organ trafficking in Nepal based on the analysis of six instances of forcible organ removal that took place between 2013 and 2019. These case studies show that Nepal is battling the serious problems of illegal organ harvesting, the black market for organs, and victim protection.

Research on the Islamic viewpoint on organ donation and transplantation in Pakistan and other Muslim nations has been conducted by Ali et al. [68]. The authors discovered that Muslims behave more negatively toward organ donation than individuals of other religions do. The reason behind this is the lack of faith and confidence in the fairness of organ donation management systems. The organ donation system in Qatar is still in its early phase of development, according to Singh et al. [69] in their work. The infrastructure and regulatory framework surrounding the organ donation management system within Qatar are still evolving and are not yet fully established or optimized. Hassall [70] discusses the issue of Australia's organ shortage and the inadequacies of its present organ donation management system, both of which require urgent policy updates to keep up with the nation's rising demand for organs. According to a report on organ donation and transplantation in Australia, between 1650 and 1700 Australians were waiting for organ transplants in 2021. According to Gawronska et al. [71], organ sellers in Belgium are paid between USD 500 and USD 10,000, whereas patients who buy organs pay between USD 40,000 and USD 200,000. This significant disparity demonstrates that brokers, recruiters, and healthcare providers earn handsomely. Further, a lack of transparency in the system provokes illicit and criminal actions. Lewis et al. [72] identify numerous problematic barriers to organ donation in European countries such as Spain and France, including organ shortages and long organ waiting lists; for example, there is a 3-year to 5-year wait for a kidney transplant.

A survey conducted in 2018 revealed the statistics of the gap between the supply and demand of organs, with 19.89% of candidates in European countries failing to undergo an organ transplant. Other data show that, because of the issue of the organ shortage in European countries, 15% to 30% of people on the waiting list die each year. This issue heightens public concern about organ trafficking.

Kragten-Heerdink et al. [73] identify organ trafficking as one of the nine prevalent challenges in the Netherlands, stating that policies and procedures to combat organ trafficking are still in their infancy in the country. Brunovskis and Surtees [74] focus on the topic of organ trafficking in Serbia, where traffickers exploit the people by selling their organs on the illicit market and giving a few Euros to the donor. Frange and Buar Ruman [75] discovered that Slovenia lacks scientific research on organ trafficking issues. Slovenia is grappling with two separate challenges: trafficking in organs, tissues, and cells as well as trafficking in human beings for organ removal. Human organ, tissue, and blood trafficking is a huge money-making enterprise for traffickers in Slovenia, where wealthy patients are willing to spend hundreds of thousands of dollars for the organs they require. According to Martin et al. [76], organ trafficking, human trafficking for organ removal, and other forms of transplant tourism are on the rise in Istanbul, Turkey. Several incidences of organ removal from living and deceased donors without their knowledge or authorization are on the rise in Turkey. Bates [77] states that, in the United States of America, due to the issue of organ scarcity, only 10% of the global demand for organs is met. According to the "United Network for Organ Donation", 20 Americans die each day while waiting for an organ transplant. The author finds that post-transplantation, long-term outcomes remain uncertain, with a 50% failure rate within a few years. Additionally, 75% of kidney transplants do not survive. The reason behind this is the inefficient donor–patient matching algorithm in the USA's organ donation management system model. Gómez et al. [78] explore how the wealthier southern states of Brazil boast stronger infrastructure and resources, facilitating easier access to transplantation services. In contrast, such comparable facilities are lacking in the impoverished northeastern states of Brazil. There is a pressing need for a unified model across all states and robust networking between hospitals in both regions.

Rawat et al. [79] discuss the topic of organ trafficking on the dark web. The scarcity of transplantable organs, along with the difficulties of preserving organs, leads to illegal and immoral organ trade on the dark web. The authors describe how the deep web has become a hub for organ harvesting, with organ traffickers exploiting the web's hidden secrets and anonymous access to promote the unlawful trading of human organs. Furthermore, Akbarialiabad et al. [80] note that the dark web has become an ideal location for illegal organ trade. According to the authors, there are a few factors that accelerate this unethical practice: first, the data and individuals are anonymous; second, the transactions are completed in cryptocurrencies such as Bitcoins, which are very difficult to trace by the government; and finally, the crypto-market covers 5–10% of the kidney transplant market. Illegal organ transplants can pose serious health hazards to both the donors and the recipients of the organs. In another review by Chalissery et al. [81], it is noted that current donor–patient matching algorithms inadequately predict transplantation survival and immune response. Typically, these algorithms prioritize patients on a first-come-first-served basis, neglecting crucial parameters that should ideally be matched between organ donors and recipients to ensure the patient's healthy post-transplantation outcome. Levan et al. [82] explored concerns related to accountability and transparency within the current organ donation management system generally. The authors highlighted challenges arising from the centralized management of all data by the government in databases, emphasizing the susceptibility to manipulation by government employees and political leaders. Additionally, Putzer et al. [83] delve into the unprecedented challenges posed by the COVID-19 pandemic, noting the rapid spread of the virus, causing extensive damage to human organs. In this critical era, the overwhelming strain on resources has significantly heightened the incidence of organ black market transactions, reaching alarming proportions. Nieto-Galván et al. [84] highlight the amplified demand for organs amid the COVID-19 pandemic, transforming the scarcity of available

organs into a public health crisis. The authors advocate for the establishment of a robust communication network among hospitals worldwide. This would enable the retrieval of organs from distant locations if they cannot be sourced locally, ensuring that patients in need have access to transplantation opportunities irrespective of geographic constraints.

Harel et al. [85] highlight the ongoing challenge of the widening gap between the organ transplant demand and the limited supply among Christians and the Jewish community. Furthermore, Ibrahim et al. [86] addressed the pressing concern of patient waitlist mortality risk resulting from the delayed procedures associated with donor–patient matching, organ allocation, and transplantation amid the COVID-19 pandemic. In other studies, by Entwistle et al. [87] and Vincent et al. [89], the authors discussed ethical concerns surrounding the organ donation and transplantation process. The authors highlighted a significant ethical dilemma arising from the substantial gap between the supply of available organs and the demand for transplantation. According to their findings, the organ allocation process tends to favor affluent and influential individuals within society, resulting in a biased distribution that disadvantages genuinely needy patients. The authors suggest the need for a transparent organ donation management model that provides a trustful environment for its stakeholders. Takaoka et al. [88] undertook comprehensive surveys encompassing both the families of patients who underwent organ transplantation and the perspectives of clinicians and organ donation coordinators. This dual-pronged approach aimed to garner insights into the experiences of all stakeholders involved in the organ donation and transplantation process. The overarching goal of these surveys was to identify shortcomings within the current system, strategically targeting areas that require improvement. The authors observed a divergence in perspectives, with patients expressing concerns about the perceived sluggishness in the organ allocation and transplantation system.

In another review, Hyde et al. [90] addressed the imperative of implementing measures to stimulate organ donation among the younger demographic. The authors underscored the necessity for a robust system that instills complete trust in people regarding the entire process of organ donation and transplantation. Their perspective emphasized that fostering confidence in the fairness of the organ allocation system is pivotal to motivating the youth to actively participate in organ donation. Zhang et al. [91] analyzed challenges posed by the COVID-19 pandemic, especially during a phase of temporary suspension of transplantation due to resource constraints. They presented a model assessing the impact of pausing liver transplants, considering two key risks: waitlist mortality for patients unable to receive transplants and an expanded waiting list with ongoing patient accrual. The authors noted increased waitlists and patient deaths during this pause. Additionally, Lentine et al. [92] directed their attention toward promoting deceased donor transplants as a viable solution to address the substantial gap between the overwhelming demand for transplantable organs and the limited supply. In their study, the authors delve into the potential benefits and strategies associated with increasing the utilization of organs from deceased donors.

3.3.2. The Literature Collected to Address Research Question RQ2

This section reviews 11 models designed using centralized technology for handling challenges that the organ donation management system is plagued with. Figure 12 shows the number of studies reviewed by publication year for addressing RQ2.

Harvey and Thompson [93] investigate the impact of the practice of multi-listing in the queue of waiting lists of patients in the United States who require organ transplantation by creating a discrete event agent-based model, programmed in Python version 2.7 using the Mesa package. The model simulates the full process of kidney transplantation. The authors examine the impact of advantaged patients, patients who are financially stable and can sign up for more than one waiting list, on the overall system of organ transplantation and note the fairness of such a system. They find that the practice of multiple registrations only slightly lengthens waiting times and queues, while simultaneously lowering the overall death rate of waiting patients, so it has no negative effects. Additionally, Heinl et al. [94] describe how the lack of human organs has given wealthy organ recipients, who do not

want to wait a long time for an organ, access to an underground market. The money obtained from the unethical trade in human organs is subsequently used to carry out additional unlawful actions. A risk model for the problem of organ trafficking is created based on the manual and automatic collection of pertinent data. The stakeholders can fully comprehend the organ trafficking supply chain, which greatly reduces the problem.

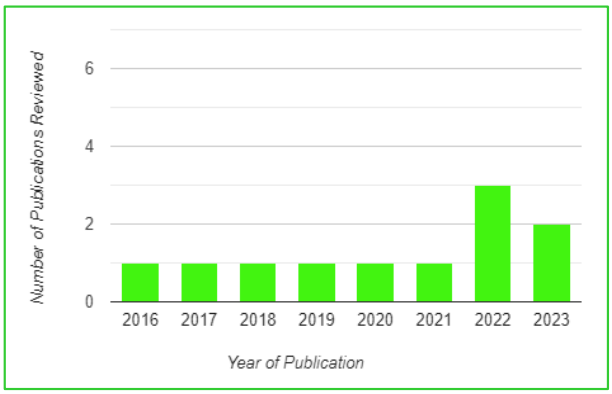


Figure 12. Studies reviewed by publication year addressing RQ2.

For fair organ allocation based on recipient health, geography, and other medical considerations, Sankar et al. [95] created an intelligent organ transplantation system using k-anonymity and a rank search algorithm. They recognize that the lack of systematic allocation procedures and the lack of privacy protection for donors, patients, and other stakeholders put the current organ allocation system at risk for bias. To solve the flaws in the current organ donation system, the authors develop a bias-free system that carefully chooses organ recipients out of concern for justice, data security, and privacy. They created a smartphone app to make it easier for organ transplant recipients to discover appropriate blood donors. The software used k-anonymity to ensure data and transaction confidentiality, while using a rank search algorithm to choose the top three most suitable donors. This system, which is built using Spyder (Python 3.7), Java Enterprise Specs, Heidi SQL, and Apache Tomcat, makes it easier to allocate impartial organs to patients who need them. Taherkhani et al. [96] create a fuzzy inference system to rank the recipients according to several kidney allocation criteria. The eight criteria for allocating a kidney are identified. These criteria are the urgency of the kidney, the PRA, the age difference between the patient and the donor, the patient's expected survival, the patient's age, the waiting period, and the blood types of the donor and recipient. Based on if-then principles, the fuzzy inference system is created to help rate patients equitably on waiting lists. According to Yoon et al. [97], the current medical procedures lack knowledge of the intricate nature of compatibility between an organ donor and its recipient, which impacts the likelihood of a successful transplant and the length of time the organ recipient lives after receiving it. A revolutionary technology, called ConfidentMatch, is put forth that trained itself using EHR data. ConfidentMatch predicts the success or failure rate of organ transplantation by examining the clinical and demographic characteristics of the donor end and receiver end.

Harvey and Weigel [98] created a Python script, namely, Transplant2mongo, that uses the OPTN to enter data into the MongoDB database. The STAR ASCII data files from the OPTN database can be converted into a MongoDB database using Transplant2Mongo. Transplant2Mongo's main goal is to handle complex non-trivial queries and perform exploratory analysis of the system of transplantation from both deceased and living donors, which is challenging on the STAR database because STAR data include a collection of intricate tab-separated files with interrelated records. The research conducted by Karami [99] focuses on heart transplant allocation disparities. The study also analyzes waiting list mortality and post-transplant survival rates. An optimization model is developed to modify the geographic boundaries in the U.S. heart allocation system. A discrete event simulation model is created to evaluate the proposed changes to the heart allocation policy.

For kidney transplants, the author proposed a simulation optimization approach for better utilization of donated kidneys through a Kidney Paired Donation (KPD) program and used an optimization model to redesign geographic boundaries in the kidney allocation system. The findings indicate that using optimization and simulation models can greatly improve equity in access to organ transplants. The objective of the research is to improve access to organ transplants.

For hospitals in times of emergency, Sivaramakrishnan et al. [100] created an online information system for organ donation and a blood bank. The database is created using MYSQL, and the distance between the blood bank and the hospital where it is needed is calculated using a geo-location system and the Haversine algorithm. The geolocation system, which is built using geo-coordinates like longitude and latitude, helps the blood bank locate the closest and finest provider that can supply the blood in the shortest period. Additionally, Joshi et al. [101] created an Android-based application called OrganReady for a variety of Android-powered mobile devices, including smartphones and tablets. It functions as a link between hospitals and organ banks as well as between organ donors and recipients of organ transplants. The approach employs machine learning to identify the ideal donor–patient match. The dataset of organ donations for various organs is used to train the model. OrganReady offers society several advantages, including its user-friendly interface, cutting-edge method of assisting the needy, ability to make hospitals around the world proactive, well-defined database, simple donor and patient access to organ banks and hospitals, and its ability to find the ideal donor–patient match.

Yuan, Y et al. [102] investigate the potential of information technology to enhance organ transplantation services. They propose the implementation of an internet-based fuzzy logic expert system to assist physicians in addressing the complex multi-criteria kidney allocation problem. A pilot fuzzy logic expert system for kidney allocation has been developed and evaluated, and its performance has been compared with two existing allocation algorithms: a priority sorting system used by the MORE program in Ontario, Canada, and a point-scoring system employed by UNOS in the USA. A simulated experiment, using real patient data, confirms that the fuzzy logic system can effectively represent the expert's decision-making in managing intricate trade-offs. Overall, the recommendations derived from the fuzzy logic system prove to be more favorably received by the expert when compared to those generated by the MORE and UNOS algorithms. In another review by Nithya and Nivetha [103], an Android application designed for organ donation and transplantation has been introduced. The app offers a user-friendly and convenient means for individuals to register as organ donors and facilitates the matching process between donors and recipients. Its primary goal is to augment the pool of organ donors. The application encompasses features for donor registration, educational resources on organ donation, and a search function to connect potential donors with recipients. According to the research findings, the adoption of this Android app has the potential to significantly boost the number of registered organ donors and enhance the efficiency of organ donation and transplantation procedures. This application can serve as an invaluable tool in raising awareness about organ donation and encouraging more individuals to sign up as donors.

3.3.3. The Literature Collected to Address Research Question RQ3

In this section, the authors explored 31 blockchain technology-based models that have been designed to deal with challenges in the organ donation and transplantation management system. Figure 13 shows the number of studies reviewed under this section by publication year.

The KAS and ETKAS algorithms for kidney donation and transplantation in the United States and Europe are evaluated by Niyigena et al. [104]. While KAS depends on KDPI and EPTS scores and uses different factors for matching patients and kidneys, ETKAS ranks patients according to blood group and point scoring. Given the difference between kidney donors and patients in need, the authors are concerned about the urgent need for a balanced organ distribution mechanism. They suggest utilizing decentralized, distributed blockchain

technology to ease international organ exchange, with donor-rich nations helping those with donor shortages. In this vision, agreements and allocation policies are created using Ethereum smart contracts transparently and reliably. These smart contracts, which are safely kept on the nodes of a blockchain network, would oversee the matching of donors and recipients, and consensus procedures would verify each contract's solution.

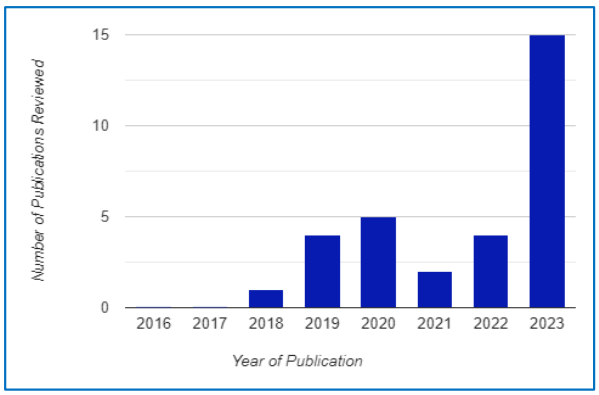


Figure 13. Studies reviewed by publication year addressing RQ3.

According to Wijayathilaka et al. [105], the lack of available human organs for transplantation has led to unethical behaviors in Sri Lanka, such as the trafficking and sale of organs on the black market. Currently, Sri Lanka uses the National Transfusion Service, which serves as a central blood bank for both government hospitals and hospitals in the private sector. The lack of security, single point of failure, and lack of transparency are problems with this central blood bank. Thus, a blockchain-based, safe, open, and intelligent blood and organ donation online service called LifeShare has been created for the Sri Lankan healthcare industry. Smart contracts are employed to construct the system's logic. The system employs a linear regression model to estimate the demand for blood over the next ten years, with an R-squared accuracy value of 0.998. The ideal donor–patient match is determined using GPS and K-Nearest Neighbors ML algorithms. Additionally, Chalissery and Asha [106] look into the issue of the improper implementation of organ donation and transplantation policies, which leads to several unethical and illegal practices in the organ transplantation system, such as the theft of organs, alterations made to the waiting lists for organs without proper justification, the improper preservation of removed organs, the black market for organs, and a lack of government policies for the system. When integrated with the organ donation and transplantation system, the append-only ledger blockchain technology and smart contracts will be very advantageous for all parties involved, including donors, recipients, transplant facilities, regulatory and advising staff, and insurance companies. The module for registration and control of the priority list is the major element of the suggested system. This module includes a donor list, a recipient waiting list, and various matching, waiting list management, and donor-seeking algorithms.

The centralized organ donation system in the United States is criticized by Jain's analysis [107] for the general public's inability to easily acquire information about organs. Organ donation and transplantation data, including the WaitlistSM and DonorNet services, are managed by UNOS, a non-governmental organization, using UNetSM, a secure web-based database. The biggest disadvantage, however, is the database's reliance on UNOS for security, stability, and waiting list correctness. To address these problems, the Hyperledger Fabric platform and the blockchain-based prototype known as OrganChain are created according to the criteria and guidelines set forth by the US Department of Health. To locate donor–patient matching within the blockchain and outside of it, two blockchain chain code solutions are developed, out of which the first solution proves to be more effective, resulting in fewer blocks being generated for write

operations, after examining variables such as the batch time-out, block size, endorsement policy, and transaction rate.

Additionally, Alandjani [108] presents a blockchain use case for organ donation as a way to combat concerns with trafficking and illegal organ sales as well as to track the legitimate donor and recipient of the organs. In this approach, the patient submits the transplantation request, and the donor signs a smart contract to donate the organ. Then a licensed nurse or doctor verifies, validates, and hashes both the donor and the patient. The ideal patient–donor match is identified after successful verification and validation, and it is then saved on the blockchain. Every transaction is securely and reliably recorded in an immutable chain of blocks, which also makes transactions transparent to the general public. According to Sawant et al. [109], the fairness of the system is one of the essential qualities that the organ donation and transplantation system should have. Systems for organ donation must locate the donor swiftly and safely. A third party would not be necessary if the organ donation used blockchain technology, which would also ensure security, transparency, and integrity throughout the entire process. As a result, a digital portal is constructed that donors can utilize to register themselves. Hospitals are in charge of this software, which matches organ donors with recipients of those organs. The system's integrity is guaranteed by the hash-chained storage algorithm. The Ethereum blockchain is used to deploy smart contracts that codify the guidelines for the organ donation procedure. To provide an equitable, effective, decentralized, secure, auditable, and traceable organ donation and transplantation process, Hawashin et al. [14] present a private Ethereum blockchain system. They create six smart contracts to manage organ removal, delivery, transplantation, patient registration, patient–donor matching, and donor medical examinations. Using the REMIX IDE and the Solidity programming language, the smart contracts are created and deployed. They are tested on a JavaScript-based virtual machine and evaluated using the Oyente tool for finding security holes in the smart contracts. The authors report EVM coverages for the smart contract codes for organ donation and transplantation of 80.9% and 99.1%, respectively. For public access, the authors provide the smart contract source code on GitHub.

Soni and Kumar [110] propose a FIFO-based web program that chooses the ideal organ donor match for each authentic patient in need of that organ. The application serves as a conduit to link the patient and the donor and prioritizes cases in which the patient needs an organ transplant immediately. It is built on decentralized, distributed, and immutable Ethereum blockchain technology, smart contracts, RSA, and SHA-256 algorithms. There are four parties in the application: the administration, the hospital/doctor, the donor, and the patient/receiver. The application consists of four tiers or layers: the blockchain, the internet, smart contracts, and the browser. Public–private key pairs are generated using digital signatures, which make the entire application trustworthy and safe. The suggested solution offers complete accessibility, transparency, and security, while maintaining cost-effectiveness and maintaining integrity. Using distributed, immutable, and secure blockchain technology, Kulshrestha et al. [111] attempt to address the issue of organ supply delays to reduce the death rate of patients. An RFID tag is used in the web portal-based system's weight-checking procedure to make sure the organ has not been tampered with while it is being transported from the donor end to the recipient end. The entire procedure has been automated on the Ethereum blockchain without the involvement of a third party. A private blockchain is built using Ganache, smart contracts are implemented using Solidity, Metamask is used to deploy the smart contracts, and web3.js is used to link the blockchain to the user interface.

DevaAnusha et al. [112] propose a framework for a blockchain-based decentralized online application for organ donation. The application includes four modules: administration, registration, system, and management. The donor–patient matching and donation-related data are maintained by the administration module. The registration module gives IDs to both patients and donors and registers them. Data matching and hashing are completed by the system module. The management module manages the donor by either accepting or

rejecting their donation and manages the patient by handling the patient's request for an organ by either accepting or rejecting the patient. The authors employ JavaScript and Java Server Pages as their scripting languages, Tomcat 7.0 as their application server, and My SQL 8.0 as their database to construct their applications on Windows 10/8. Le et al. [113] develop BloodChain, a blockchain-based blood management system, utilizing Hyperledger Fabric technology, which offers comprehensive data on blood consumption and blood disposal. One chain code in Hyperledger Fabric is developed for the system to store, query, and provide total transparency for all data about blood. Medical staff, donors, patients, transportation, and ledgers are the five main components of the model, and the first four of these send and receive blood-related data from the fifth component.

Additionally, Pillai et al. [114] discuss the crimes connected to organ donation that take place in India. So, the use of decentralized blockchain technology is suggested for the preservation of donor organ data. The approach uses blockchain technology and is divided into three phases: key generation, DES encryption, and DES decryption. The healthcare system model includes various modules for donor registration, which create new donor IDs, an authentication module, a module for data encryption using the DES encryption method, and a module for sharing data on a blockchain. In another review, Dajim et al. [115] suggest a decentralized secure web application for organ donation utilizing blockchain to satisfy Saudi Arabia's demand for organs, which operates on a first-come-first-served basis, unless there is an emergency case. The application's goal is to prevent the death of patients who are waiting a long time for organs by offering complete transparency, the quickest solution, and modern security. Three parts make up the application: the administration, donor, and system. The administration module is in charge of handling the location and name of donation centers, general information about those centers, donation-related data, patient registration, organ search, and matching data viewing. The donor module maintains information about donations, monitors the progress of requests, and registers donors with their full information. The system module distributes data, performs data hashing, and gives patient and donor user IDs and passwords.

Ranjan et al. [116] emphasize the benefits of distributed and decentralized alternatives while criticizing the fragility and single-point failure of the current centralized organ donation information system. For managing organ and tissue transplants, they propose a transparent, secure DApp build with NodeJS and components from the JSON web token, crypts, passport, express, mongoose, and Axios libraries. The Truffle framework's smart contracts that are written in the Solidity programming language contain the DApp's logic. The IPFS is used to hash EMRs, lowering the cost of data upload. To do testing, multiple fictitious ether accounts have been created in Ganache, and Metamask has been used to execute transactions, bridging the blockchain and the browser. Real test data are used to deploy the DApp on the Ropsten test network with participants including donors, hospitals, and receivers. The DApp has modules for patient–donor matching, hash generation, donor inclusion, and recipient addition. Additionally, it presents information and produces public and private keys for donors and patients.

Quynh et al. [117] propose an innovative system to address the dearth of comprehensive blood data in the existing framework. The system facilitates blood management by offering an extensive range of data, including information on blood consumption and disposal. The proposed system is constructed upon the architecture of Hyperledger Fabric which records and manages blood-related information to enhance the handling of blood supply and demand within national institutions, thereby simplifying emergency response procedures. In another review, Parmar et al. [118] propose a secure, efficient, and scalable solution in the form of a blockchain-based organ donation management system by leveraging smart contracts to automate and expedite the organ donation process, resulting in a reduced overall processing time. The blockchain-based ODP enhances the search for compatible donors, eliminating intermediaries and ensuring security, integrity, and transparency through a decentralized network.

Chavez et al. [119] state that blockchain emerges as a promising solution to assist in the organ governance and supply chain, from the initial assessment to post-donor analysis, by establishing a single source of truth, which otherwise is a complex process. Blockchain's immutability, traceability, and security attributes provide transparency and seem well-suited for managing organ procurement and placement supply chains and for data analysis in pre- and post-operative events. Additionally, Sajwan et al. [120] explore an innovative platform, with the adoption of the Ethereum blockchain, for matching organ transplants and serving healthcare organizations, donors, and recipients in a secure and traceable manner, thereby reducing organ trafficking. According to the authors, the rising prominence of blockchain technology represents an ideal choice for enhancing data security and scalability and offers a promising avenue for addressing real-world challenges in organ donation.

Varshney et al. [121] propose a Hyperledger Fabric blockchain-based system that guarantees decentralization, security, traceability, privacy, and trustworthiness in organ donation and transplantation. Authors suggest that, to ensure a fair and efficient organ donation and transplantation process, the adoption of blockchain technology offers a promising solution. The authors also conduct confidentiality, safety, and privacy assessments comparing the proposed solution with existing methods and find that a blockchain-based system proves to be more efficient. In another review, Gaushik et al. [122] introduce a DApp based on blockchain technology aimed at efficiently connecting recipients with blood donors during emergencies. Vital personal information, including names, locations, blood types, and donation histories, is securely stored on the blockchain's distributed ledger through the IPFS. According to the authors, one of the primary barriers to blood donation is the lack of awareness and motivation among potential donors. To address this issue, the work proposes the implementation of a gamification system within the blood donation process, where NFTs are awarded as badges to donors as incentives for their contributions. These NFT badges can serve as a unique form of recognition and reward for donors, potentially encouraging more people to participate in blood donation efforts. Furthermore, the paper delves into the design of smart contracts that play a pivotal role in storing and managing donor and recipient data on the blockchain ledger as well as the mechanism for issuing NFTs to donors.

Additionally, Luo, Y et al. [123] developed a blood donation platform that leverages both blockchain technology and the KNN algorithm. This system employs blockchain for storing critical blood donation information and hash file details, utilizes the IPFS to safeguard the real blood donor's identity image and signature files, and employs the KNN algorithm to identify the nearest blood supply center with a specific blood type. This enables prompt deployment during hospital ischemic situations, reducing mortality due to inadequate blood supply in the blood bank. This initiative amalgamates traditional blood donation with blockchain and KNN, ensuring the privacy and security of blood donors, facilitating blood source tracking and efficiently matching the nearest blood bank to address hospital ischemia. According to Quoc, D. N. T. [124], the existing blood management processes are predominantly manual, involving data entry performed by medical staff. Data associated with the entire blood donation process, including information about donors, recipients, and inventory, are stored centrally, making it challenging to ensure reliable access and centralized data security. The risk of personal information theft or data loss is a significant concern. To address these limitations, authors introduce a blockchain-based approach to blood management, utilizing a decentralized distributed ledger named "BloodMan-Chain". The design of the BloodMan-Chain model leverages blockchain technology to manage comprehensive information about blood and its products. This model ensures transparency, traceability, and security in the blood supply chain. BloodMan-Chain implements a proof of concept using Hyperledger Fabric.

Suneetha and Reddy [125] present a remedy employing a private Ethereum blockchain to automate blood donation management in a decentralized, transpar-

ent, traceable, auditable, private, secure, and trustworthy manner. The suggested solution efficiently moves non-critical and extensive data off-chain, utilizing a decentralized IPFS for enhanced efficiency. The system's architecture, sequence diagrams, entity-relationship diagrams, and algorithms have been delineated to offer a concise insight into the functioning of the blood donation management solution. To ensure the solution's security and performance, a comprehensive security analysis has been conducted. Furthermore, the authors made smart contract code publicly available on GitHub for transparency and accessibility. Panda and Mazumder [126] introduce a blockchain-based solution to oversee the kidney supply chain, in light of the scarcity of available kidney organs for transplantation and the need to ensure their utmost care. This framework creates a secure system for precise monitoring of the organ's whereabouts and handling, ensuring the organ's well-being from the donor to the recipient. Furthermore, a machine learning algorithm to continuously assess the organ's health using various metrics has been incorporated, allowing for the early detection of potential kidney damage. Furthermore, Ajay et al. [127] propose a web-based application with a decentralized structure that serves as an efficient platform for hospitals, organ recipients, and donors to connect. This architecture permits users to engage in a blockchain-based smart contract without the need to manage their keys, while still upholding the security and transparency advantages intrinsic to decentralized systems. Consequently, it offers a fine equilibrium between decentralization and convenience. The integration of off-chain databases enhances data security, accessibility, and overall efficiency. The utilization of these features has the potential to address several challenges within the healthcare sector, including the elimination of convoluted intermediary networks and the enhancement of transaction traceability. Furthermore, this solution is cost-effective and can assist patients in averting the exorbitant expenses associated with transplantation. Ghosh and Dutta [128] propose blockchain technology as a substitute for centralized systems to enhance transparency, security, and efficiency in the organ donation process. The Hyperledger Fabric framework has been harnessed to formulate a network model for the organ donation system by conceptualizing and deploying a prototype system featuring smart contracts through the Amazon Managed Blockchain Service. Furthermore, a client application has been developed that employs the Fabric SDK to communicate with the network and execute diverse tasks. To assess the system's performance, comprehensive testing using the Hyperledger Caliper benchmarking tool has been executed. In the testing environment, the system attains a peak actual transmission rate of 389.1 TPS for record creation and 508.4 TPS for record retrieval. At a transmission rate of 800 TPS, the system utilizes 12.16 s to fulfill a record creation request and 3.71 s for a record retrieval request.

Gowri et al. [129] introduce a fully decentralized, secure, traceable, auditable, private, and trustworthy DApp built on the private Ethereum blockchain to streamline the coordination of organ donation and transplantation. Six smart contract algorithms have been developed, tested, and validated. Through a research-driven evaluation of privacy, security, and confidentiality, and a comparative analysis with existing alternatives, the effectiveness of our proposed solution has been checked. Soni et al. [130] have developed a platform based on the Polygon blockchain, employing smart contracts to automate various facets of organ donation and transplantation. This includes tasks such as verifying the identities of donors and recipients, managing organ matching, and recording organ donation details. Patient data are securely stored in MongoDB, with decentralized digital identities ensuring data security and privacy. An administrative dashboard provides a user-friendly interface for system management, while routine data analysis and monitoring track essential metrics. The authors assert that the adoption of blockchain technology holds the potential to improve the safety and ethical integrity of the organ transplantation process, combat organ trafficking, and enhance the accessibility of life-saving organ transplants. Furthermore, Anselmo et al. [36] present a review exploring the potential future impact of blockchain and DLT in the realm of organ transplantation, specifically in addressing dispar-

ities. The authors discovered that the applications of DLT include preoperative assessment of deceased donors, international crossover programs using global waitlist databases, and combating black-market donations and counterfeit drugs. DLT's attributes of distribution, efficiency, security, traceability, and immutability are instrumental in mitigating inequalities and discrimination.

4. Results and Analysis

This section presents the results and analysis of the literature covered in Section 3.3, focusing on addressing the four research questions introduced in Section 3.1.2. A total of 85 publications have been reviewed, with 67 appearing in journals, 16 in conference proceedings, and 2 as post-doctoral dissertations. Among these publications, 43 were examined to address RQ1, 11 for RQ2, and 31 for RQ3, respectively. The exploration of research question RQ4 will be based on a thorough analysis of the findings from RQ2 and RQ3.

4.1. Analysis of the Literature Reviewed for Addressing RQ1

To address research question RQ1, the authors scrutinized 43 publications, in Section 3.3.1, published from the year 2017 to 2023, to elucidate the challenges encountered by organ donation management systems across 30 randomly selected countries. Figure 14 provides a clear image of the different challenges that the worldwide organ donation management system encounters, allowing for analysis and the creation of potential solutions. Table 10 lists the issues that different nations confront in their management systems, and Table 11 compiles these issues and mentions the global prevalence of these issues in percentage form. The outcomes of this analysis underscore the predominant concern surrounding organ trafficking, illicit organ trade, the lack of stakeholders' trust in the system, and unethical organ allocation. The primary catalyst for these issues has been the absence of transparency of processes for stakeholders within the organ donation management framework. The formula used to calculate the Global Issue Prevalence is as follows:

$$\text{Global Issue Prevalence (\%)} = (\text{Number of countries facing the issue} / \text{Total countries reviewed}) * 100$$

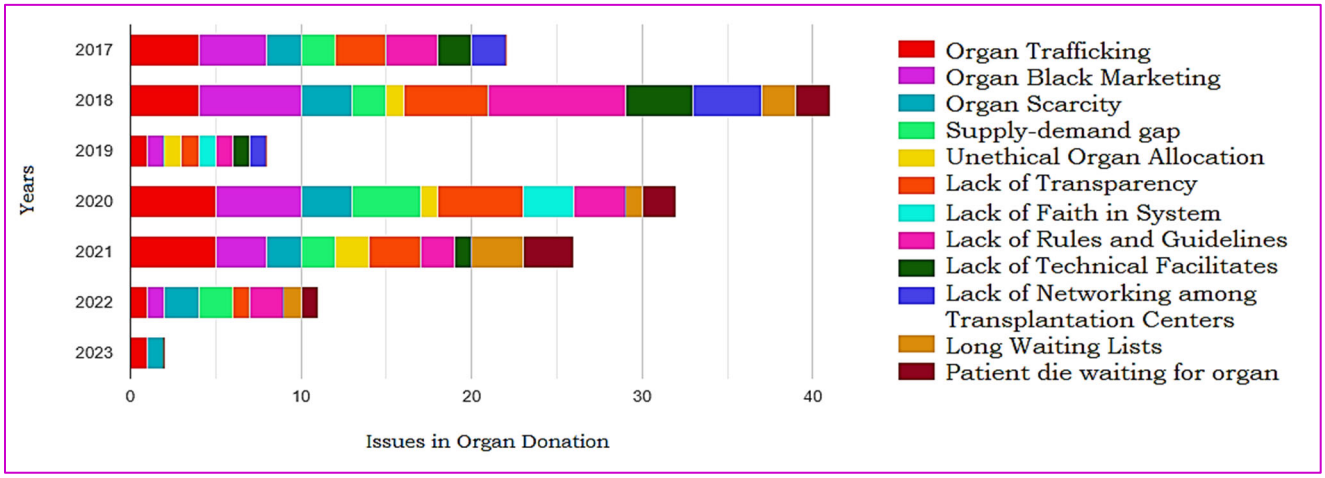


Figure 14. A year-wise exploration of global organ donation management system challenges.

Table 10. Global organ donation management system issues (sorted country-wise).

Sr. No.	Study	Country Surveyed	Year of Survey	Issues Faced by Organ Donation Management Systems											
				Organ Trafficking	Organ Black Marketing	Organ Scarcity	Supply-Demand Gap	Unethical Organ Allocation	Lack of Transparency	System Distrust	Absence of Guidelines	Tech Resource Gap	Transplant Center Networking Gap	Long Waitlists	Organ Waitlist Fatalities
1	Bates [77]	America	2020			✓	✓			✓				✓	✓
2	Hassall [70]	Australia	2022			✓	✓	✓			✓		✓	✓	✓
3	Moniruzzaman [54]	Bangladesh	2018	✓	✓			✓	✓	✓	✓		✓		
4	Gawronska et al. [71]	Belgium	2020	✓	✓			✓	✓	✓					
5	Gómez et al. [78]	Brazil	2018					✓	✓	✓	✓	✓	✓	✓	✓
6	Shi et al. [55]	China	2020	✓	✓			✓	✓						
7	Shi et al. [56]	China	2020						✓	✓	✓				✓
8	Columb [50]	Egypt	2017	✓	✓	✓	✓		✓		✓				
9	Lewis et al. [72]	France	2021	✓		✓	✓							✓	✓
10	Sachdeva [57]	India	2017	✓	✓	✓	✓	✓		✓	✓	✓	✓		
11	Nallusamy [58]	India	2018			✓	✓	✓		✓	✓	✓	✓	✓	✓
12	Saxena et al. [59]	India	2020				✓		✓	✓					
13	Mukherjee et al. [60]	India	2023	✓		✓									
14	Yanto et al. [61]	Indonesia	2021	✓	✓				✓	✓					
15	Kiani et al. [62]	Iran	2018		✓	✓		✓		✓	✓	✓	✓		✓
16	Berzon [63]	Israel	2018		✓	✓	✓								
17	Cho [64]	Korea	2019					✓	✓	✓	✓	✓	✓	✓	✓
18	Zulaikha et al. [65]	Malaysia	2018	✓	✓			✓	✓						
19	Kragten et al. [73]	Netherlands	2018	✓	✓			✓	✓	✓	✓				
20	Thapa [66]	Nepal	2021	✓	✓			✓	✓	✓				✓	✓
21	Gawronska [67]	Nepal	2021	✓	✓			✓	✓		✓				
22	Obaniet al. [51]	Nigeria	2020	✓	✓	✓	✓			✓					
23	Ali et al. [68]	Pakistan	2020					✓		✓					
24	Singh et al. [69]	Qatar	2018					✓			✓	✓	✓	✓	✓
25	Brunovskis et al. [74]	Serbia	2017	✓	✓				✓	✓					
26	Frangež et al. [75]	Slovenia	2017	✓	✓				✓	✓		✓	✓		
27	Iroanya [52]	South Africa	2018	✓	✓			✓	✓	✓	✓		✓		
28	Yesufu [53]	South Africa	2020	✓	✓	✓	✓	✓							
29	Lewis et al. [72]	Spain	2021	✓		✓	✓						✓	✓	✓
30	Martin et al. [76]	Turkey	2019	✓	✓			✓							
Total				19	18	12	11	18	16	18	13	07	11	09	11

Table 11. Organ donation management system issues and their global prevalence.

Sr. No.	Issue Category	Global Issue Prevalence
1	Organ trafficking	19/30 (63.3%)
2	Black marketing of organs	18/30 (60%)
3	System distrust	18/30 (60%)
4	Unethical organ allocation	18/30 (60%)
5	Lack of transparency	16/30 (53.3%)
6	Absence of guidelines	13/30 (43.3%)
7	Organ scarcity	12/30 (40%)
8	Supply–demand gap	11/30 (36.7%)
9	Organ waitlist fatalities	11/30 (36.7%)
10	Transplant center networking gap	11/30 (36.7%)
11	Long waitlists	09/30 (30%)
12	Tech resource gap	07/30 (23.3%)

4.2. Analysis of the Literature Reviewed for Addressing RQ2

To address research question RQ2, the authors scrutinized 11 publications, in Section 3.3.2, published from the year 2016 to 2023, to explore the models that utilize centralized technology for designing organ donation management systems. It has been noted that these centralized models predominantly employ technologies such as Python, Java, SQL, and Android Technology. These models tackle various issues in the organ donation management system, as depicted in Table 12. Table 13 compiles the issues addressed by these models along with issue address percentage, sorted in descending order of percentage. The formula used to calculate the issue address percentage of centralized technology-based models is as follows:

$$\text{Issue address percentage} = (\text{Number of models handling the issue}/\text{Total models considered}) * 100$$

Table 12. Centralized technology-based models for organ donation management systems.

Study	Outcome	Tool	Major Finding	Issues Addressed											
				Organ Trafficking	Organ Black Marketing	Organ Scarcity	Supply-Demand Gap	Unethical Organ Allocation	Lack of Transparency	System Distrust	Absence of Guidelines	Tech Resource Gap	Transplant Center Networking Gap	Long Waitlists	Organ Waitlist Fatalities
[93]	Agent-based model	Python	Impact of multiple registrations on waiting lists			✓					✓	✓	✓	✓	✓
[98]	Transplant2Mongo Script	Python	Optimal DBMS for organ donation and transplantation data and complex queries				✓			✓		✓	✓		
[94]	Risk Model	Not mentioned	Addressed organ trafficking	✓	✓		✓			✓					
[101]	OrganReady System	Android Studio	Connecting hospitals and blood banks			✓	✓								
[95]	Mobile Application	Python, Java, SQL	Equitable organ allocation			✓		✓		✓	✓	✓	✓	✓	✓

Table 12. *Cont.*

Study	Outcome	Tool	Major Finding	Issues Addressed											
				Organ Trafficking	Organ Black Marketing	Organ Scarcity	Supply-Demand Gap	Unethical Organ Allocation	Lack of Transparency	System Distrust	Absence of Guidelines	Tech Resource Gap	Transplant Center Networking Gap	Long Waitlists	Organ Waitlist Fatalities
[99]	Optimization and Simulation Model	Python and Gurobi	Improved access to organ transplants					✓						✓	✓
[100]	Online Information System	MYSQL	Located nearest ideal organ				✓	✓						✓	✓
[96]	Fuzzy Inference System	Not mentioned	Optimal kidney allocation and fair waitlist ranking	✓	✓	✓	✓			✓	✓			✓	✓
[97]	ConfidentMatch System	Not mentioned	Identified ideal donor–recipient match for lifelong transplant success			✓	✓	✓			✓			✓	✓
[102]	Fuzzy Logic Expert System	Not mentioned	Developed an online fuzzy logic expert system for managing kidney allocation	✓	✓	✓	✓	✓						✓	✓
[103]	Android application	Android Studio	Developed an Android app for linking patients with the optimal donor			✓	✓	✓						✓	
		Total		3	3	7	8	6	0	4	4	3	3	8	7

Table 13. The issue category and issue address percentage of centralized technology-based models.

Sr. No.	Issue Category	Issue Address Percentage
1	Supply–demand gap	08/11 (72.7%)
2	Long waitlists	08/11 (72.7%)
3	Organ scarcity	07/11 (63.6%)
4	Organ waitlist fatalities	07/11 (63.6%)
5	Unethical organ allocation	06/11 (54.5%)
6	System distrust	04/11 (36.4%)
7	Absence of guidelines	04/11 (36.4%)
8	Organ trafficking	03/11 (27.3%)
9	Black marketing of organs	03/11 (27.3%)
10	Transplant center networking gap	03/11 (27.3%)
11	Tech resource gap	03/11 (27.3%)
12	Lack of transparency	00/11 (00.0%)

4.3. Analysis of the Literature Reviewed for Addressing RQ3

To address research question RQ3, the authors scrutinized 31 publications, in Section 3.3.3, published from the year 2016 to 2023, to study organ donation management systems that have been developed using decentralized blockchain technology, as illustrated in Table 14. Figure 15 displays a pie chart illustrating the proportion of models utilizing the Ethereum, Hyperledger Fabric, IPFS, and Polygon blockchains as a management platform for organ donation systems. Figure 16 presents a pie chart comparing the

number of models that utilized private blockchains with those that used public blockchains for storing the relevant data and transactions. A pie chart shown in Figure 17 contrasts the proportion of the models that have implemented smart contracts to carry out the operations within the model with the proportion of models that have not. Additionally, the proportion of models that designed a DApp for the interaction of stakeholders is compared to those that have not, through a pie chart in Figure 18. It has been noted that 54.8% of the models employed the Ethereum blockchain, while 19.4% utilized the Hyperledger Fabric blockchain to manage the organ donation system. Another 6.5% of the models used the IPFS, whereas 3.2% used the Polygon blockchain for developing models for organ donation management. On the contrary, 16.1% of the models did not mention the type of blockchain deployed. Additionally, 32% of the models utilized private blockchains, while 51.9% utilized public blockchains for storing relevant data and transactions. In contrast, 16.1% of the models did not specify the type of blockchain used. Furthermore, it has been observed that 58.1% of the studies have implemented smart contracts to enhance the system, while the remaining 41.9% of the studies have not implemented smart contracts. Additionally, it has been found that 38.7% of studies have designed DApps for better user interaction, while the remaining 61.3% have not designed DApps. Moreover, from the analysis of Table 14, it has been noted that the models developed using blockchain technology have addressed the majority of issues confronting organ donation management systems. Table 15 compiles the issues addressed by these models along with the issue address percentage, sorted in descending order of percentage. The formula used to calculate the issue address percentage of blockchain technology-based decentralized models is as follows:

$$\text{Issue address percentage} = (\text{Number of models handling the issue}/\text{Total models considered}) * 100$$

Table 14. Blockchain technology-based decentralized models for organ donation management systems.

Study	Blockchain Deployed?	Blockchain Type	Smart Contracts Implemented?	DApp Designed?	Issues Addressed											
					Organ Trafficking	Organ Black Marketing	Organ Scarcity	Supply-Demand Gap	Unethical Organ Allocation	Lack of Transparency	System Distrust	Absence of Guidelines	Tech Resource Gap	Transplant Center Networking Gap	Long Waitlists	Organ Waitlist Fatalities
[131]	Ethereum	Public	Yes	Yes	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
[132]	Not Mentioned	-	No	No	✓	✓	✓	✓	✓	✓	✓				✓	✓
[104]	Ethereum	Public	Yes	No	✓	✓	✓	✓	✓	✓	✓				✓	✓
[105]	Ethereum	Public	Yes	No	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
[106]	Not Mentioned	-	No	No	✓	✓	✓	✓	✓	✓	✓					
[107]	Hyperledger Fabric	Private	No	No		✓		✓	✓	✓		✓	✓	✓	✓	✓
[108]	Ethereum	Public	Yes	No	✓	✓	✓	✓		✓	✓	✓			✓	✓
[109]	Ethereum	Public	Yes	No	✓	✓				✓				✓	✓	✓
[14]	Ethereum	Private	Yes	No	✓	✓			✓	✓	✓		✓		✓	✓
[110]	Ethereum	Public	Yes	Yes	✓	✓	✓	✓	✓	✓	✓		✓		✓	

Table 14. *Cont.*

Study	Blockchain Deployed?	Blockchain Type	Smart Contracts Implemented?	DApp Designed?	Issues Addressed											
					Organ Trafficking	Organ Black Marketing	Organ Scarcity	Supply-Demand Gap	Unethical Organ Allocation	Lack of Transparency	System Distrust	Absence of Guidelines	Tech Resource Gap	Transplant Center Networking Gap	Long Waitlists	Organ Waitlist Fatalities
[111]	Ethereum	Private	Yes	No	✓	✓			✓	✓	✓			✓	✓	✓
[112]	Ethereum	Public	Yes	Yes	✓	✓			✓	✓	✓				✓	
[113]	Hyperledger Fabric	Private	No	No	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
[114]	Not Mentioned	-	No	No	✓	✓				✓	✓			✓	✓	✓
[115]	Ethereum	Public	Yes	Yes	✓	✓	✓	✓		✓	✓			✓	✓	
[116]	Ethereum	Public	Yes	Yes	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓
[117]	Hyperledger Fabric	Private	No	No	✓	✓	✓	✓	✓	✓	✓		✓		✓	
[118]	Ethereum	Public	Yes	Yes	✓	✓	✓	✓		✓	✓	✓			✓	✓
[119]	Not Mentioned	-	No	No	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
[120]	Ethereum	Public	No	No	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓
[121]	Hyperledger Fabric	Private	No	No	✓	✓	✓	✓	✓	✓	✓		✓		✓	
[122]	IPFS	Public	Yes	yes	✓	✓	✓	✓		✓	✓	✓			✓	✓
[123]	IPFS	Public	No	No	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓
[124]	Hyperledger Fabric	Private	Yes	Yes	✓	✓	✓	✓		✓	✓	✓			✓	✓
[125]	Ethereum	Private	Yes	Yes	✓	✓	✓	✓	✓	✓	✓		✓		✓	
[126]	Ethereum	Public	No	No	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
[127]	Ethereum	Public	Yes	Yes	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓
[128]	Hyperledger Fabric	Private	No	No	✓	✓	✓	✓	✓	✓	✓		✓		✓	
[129]	Ethereum	Private	Yes	yes	✓	✓	✓	✓		✓	✓	✓			✓	✓
[130]	Polygon	Public	Yes	Yes	✓	✓	✓	✓	✓	✓	✓		✓		✓	
[36]	Not mentioned	-	No	No	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Total			30	31	25	25	23	31	29	12	18	11	30	22

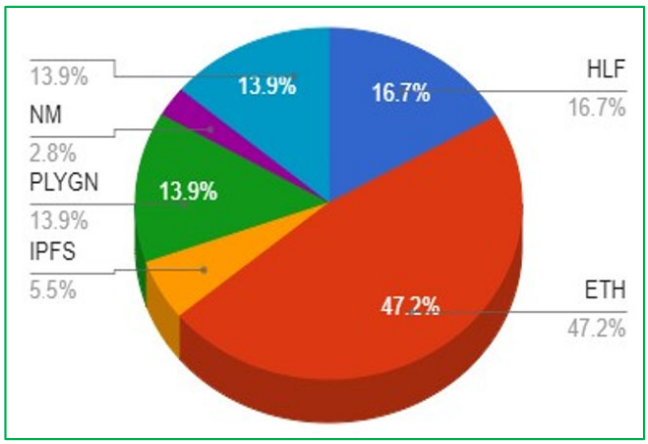


Figure 15. Blockchain usage: Ethereum (ETH) vs. Hyperledger Fabric (HLF) vs. InterPlanetary File System (IPFS) vs. Polygon (PLYGN) vs. Not Mentioned (NM).

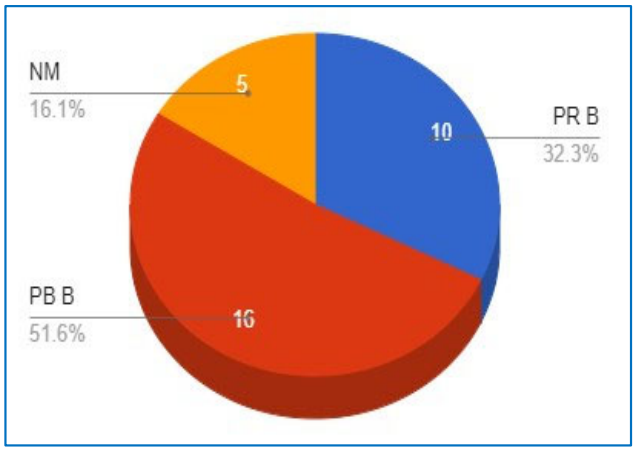


Figure 16. Blockchain type: Private Blockchain (PR_B) vs. Public Blockchain (PB_B) vs. Not Mentioned (NM).

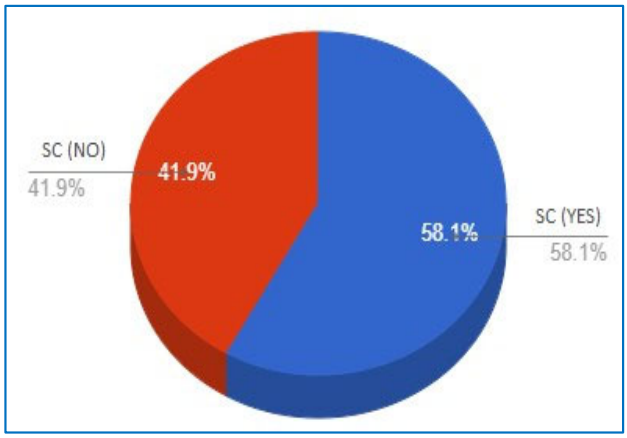


Figure 17. Smart contracts coded vs. not coded.

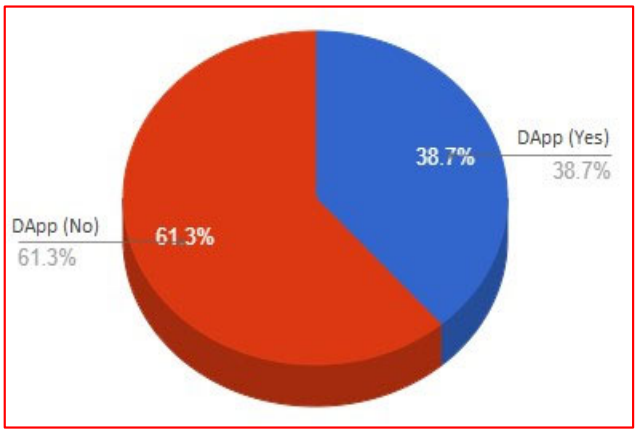


Figure 18. Decentralized application (DApp) designed vs. not designed.

Table 15. The issue category and issue address percentage of blockchain-based models.

Sr. No.	Problem Category	Issue Address Percentage
1	Lack of transparency	31/31 (100%)
2	Black marketing of organs	31/31 (100%)
3	Organ trafficking	30/31 (96.8%)
4	Long waitlists	30/31 (96.8%)
5	System distrust	29/31 (93.5%)
6	Supply–demand gap	25/31 (80.6%)
7	Organ scarcity	25/31 (80.6%)
8	Unethical organ allocation	23/31 (74.2%)
9	Organ waitlist fatalities	22/31 (71.0%)
10	Tech resource gap	18/31 (58.1%)
11	Absence of guidelines	12/31 (38.7%)
12	Transplant center networking gap	11/31 (35.5%)

4.4. Exploration of RQ4 Based on Analysis of the Literature Reviewed for Addressing RQ2 and RQ3

This section addresses the taxonomy of studies based on two categories: models developed using blockchain technology and those developed using centralized technology for handling challenges in the management of organ donation systems. The major goal is the identification of the superior category of models among the two. Figure 19 lists the total number of studies reviewed over a given period under two mentioned categories. After analyzing the findings presented in Sections 4.2 and 4.3, it is evident that both categories of models effectively tackle various issues within the organ donation management system. Figure 20 provides a comparative assessment of the capabilities of these models in addressing the issues. The visual representation in this figure demonstrates the superiority of blockchain technology-based models in resolving problems related to organ donation and transplantation when compared to centralized technology-based alternatives. Table 16 compares the percentage of issues addressed by both models, distinctly showcasing the advantage of utilizing blockchain technology in resolving challenges associated with organ donation management systems when contrasted with centralized alternatives.

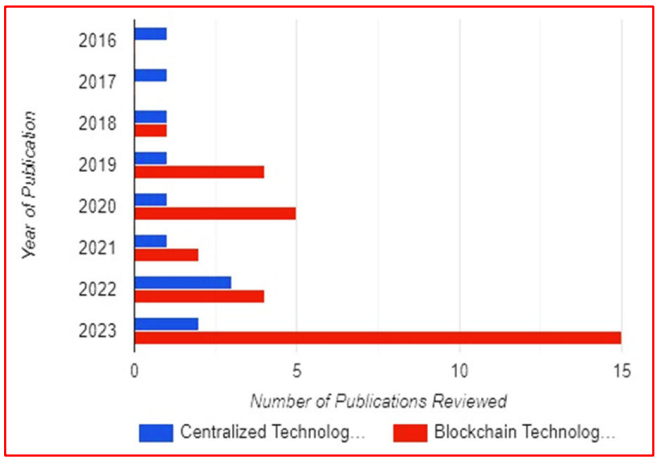


Figure 19. An annual examination of studies in two categories.

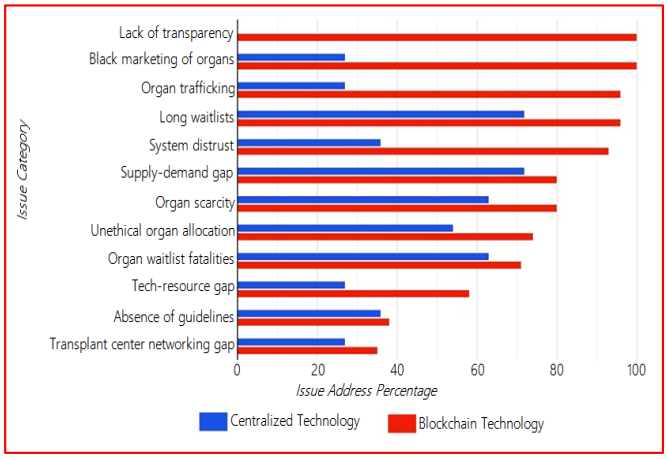


Figure 20. A comparative assessment of the issue assessing capabilities of both solutions.

Table 16. The issue address percentage comparison of both solutions and the identification of a superior solution.

Sr. No.	Problem Category	Issue Address Percentage		Superior Solution Identification
		Centralized Technology-Based Models (Obtained from Table 13)	Blockchain Technology-Based Models (Obtained from Table 15)	
1	Lack of transparency	00.0%	100%	Blockchain-based (+100%)
2	Black marketing of organs	27.3%	100%	Blockchain-based (+72.7%)
3	Organ trafficking	27.3%	96.8%	Blockchain-based (+69.5%)
4	Long waitlists	72.7%	96.8%	Blockchain-based (+24.1%)
5	System distrust	36.4%	93.5%	Blockchain-based (+57.1%)
6	Supply–demand gap	72.7%	80.6%	Blockchain-based (+7.9%)

Table 16. *Cont.*

Sr. No.	Problem Category	Issue Address Percentage		Superior Solution Identification
		Centralized Technology-Based Models (Obtained from Table 13)	Blockchain Technology-Based Models (Obtained from Table 15)	
7	Organ scarcity	63.6%	80.6%	Blockchain-based (+17%)
8	Unethical organ allocation	54.5%	74.2%	Blockchain-based (+19.7%)
9	Organ waitlist fatalities	63.6%	71.0%	Blockchain-based (+7.4%)
10	Tech resource gap	27.3%	58.1%	Blockchain-based (+30.8%)
11	Absence of guidelines	36.4%	38.7%	Blockchain-based (+2.3%)
12	Transplant center networking gap	27.3%	35.5%	Blockchain-based (+8.2%)

5. The Identification of Research Gaps and Future Directions

This section provides an overview of the significant gaps and constraints in the existing research as revealed through the analysis and discussion of the reviewed literature in Section 4.

5.1. The Integration of IoT and Blockchain for Organ Donation Management Systems

The majority of the work under assessment focuses on the applicability of blockchain technology and traditional centralized technology for managing the organ donation and transplantation system and handling issues including trafficking and black-marketing of organs, unethical organ allocation, a lack of stakeholder trust, and inadequate transparency of processes. Nevertheless, the studies do not delve into the monitoring of the donated organ during transportation from the donor's location to the recipient's destination, aiming to prevent its contamination and subsequent wastage. The IoT can be used in conjunction with the solutions examined, although this is still an underexplored domain in the context of organ donation and transplantation systems. Each organ is associated with defined post-removal survival durations and precise temperature requirements for preservation within the organ container, as elucidated in Table 17 [133–136]. Additionally, the humidity level inside the organ container should range between 80% and 95% [137–139].

Table 17. Organ storage requirements: duration and temperature.

Sr. No.	Organ	Survival Time (Hours)	Temperature Requirement
1	Kidney	24–36	0–80 °C
2	Liver	8–12	0–60 °C
3	Lung	4–6	0–80 °C
4	Intestine	4–6	0–40 °C
5	Heart	4–6	0–40 °C
6	Cornea	48	20–60 °C

Future research endeavors may involve the incorporation of IoT-enabled sensors within the organ container, as illustrated in Figure 21 and Table 18. These sensors could actively monitor the organ's immediate environment and collect real-time data regarding factors such as temperature and humidity inside the organ container during transit from

the donor end to the patient. Furthermore, the sensors could secure the organ container by preventing its opening, tilting, or falling during transportation. Subsequently, data generated by the sensors could be transmitted to smart contracts deployed on the blockchain that serve to validate the safe transfer of organs. In case of any violations or anomalies, such as deviations in temperature or humidity inside the organ container beyond the specified thresholds or the opening, tilting, or falling of the organ container, automatic alerts and notifications could be promptly sent to the patient to whom that organ has been allotted or to the patient's doctor. Additionally, an IoT-enabled tracking device could be installed in the organ delivery vehicle to monitor the organ's location and optimize the route to the intended destination, mitigating potential delays [140].

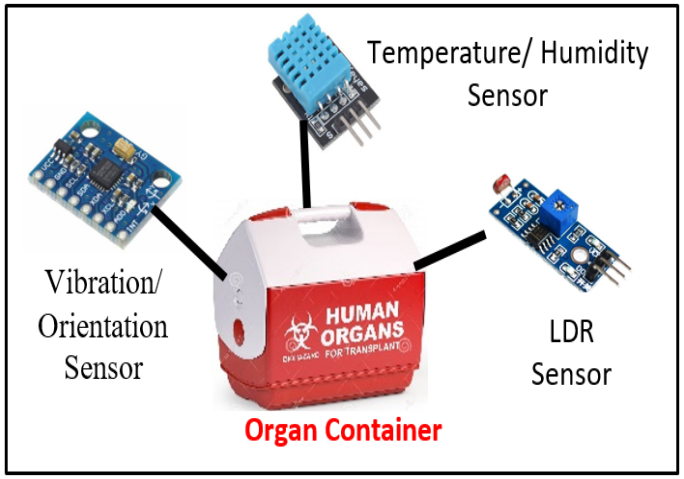


Figure 21. IoT sensors embedded inside an organ container.

Table 18. Name and purpose of each sensor.

Sensor Name	Purpose
Lid Open/Close Detector (LDR Sensor)	Ensures the lid of the organ container remains closed during shipment by detecting the light intensity inside the container
Temperature Sensor (DHT 11 Sensor)	Measures real-time temperature inside organ container
MPU 6050	Monitors vibration and orientation of organ container to prevent its tilting and falling
Humidity Sensor (DHT 11 Sensor)	Measures real-time humidity level inside organ container

5.2. The Use of Artificial Intelligence in the System of Organ Donation Management

Artificial intelligence can play a pivotal role in enhancing the management of organ donation systems, which further leads to increased efficiency and ultimately saves more lives. Future investigations can focus on leveraging AI for the improvement of the management of organ donation and transplantation systems. AI algorithms can assess various factors, such as medical history, blood type, and organ compatibility, optimizing the matching process between donors and recipients [141–143]. This optimization ensures the creation of the most suitable matches, thereby enhancing the probability of successful transplants. AI can evaluate factors like the severity of a patient's condition, using this information to prioritize individuals on the waiting list and guarantee that organs are allocated to those with the most urgent needs. Additionally, AI contributes to verifying the authenticity of donor and recipient information, thereby minimizing the risk of fraud in the organ donation process, which is an essential element in preserving the integrity of the organ donation system. Continuous post-transplant monitoring of recipients can be another application of AI, involving the analysis of data from wearable devices or remote monitoring systems to promptly identify signs of organ rejection or complications [144–146].

5.3. The Implementation of the Organ Donation System on Blockchains Other than Ethereum

In Section 4.3, it has been observed that 47.2% of publications on the utilization of blockchain technology for organ donation management have employed the Ethereum blockchain, which incurs substantial Ether costs for deployment. Future research endeavors may consider alternative blockchains with lower or zero deployment costs, such as Hyperledger Fabric, Matic, Solana, Cardano, Algorand, and Binance, among others.

5.4. Designing a Decentralized Application for Organ Donation Management System

It has been noted in Section 4.3 that only 38.7% of publications on the utilization of blockchain technology for organ donation management have developed decentralized applications to facilitate stakeholder interaction with the system. Future emphasis could be directed toward creating improved decentralized applications, allowing patients to input their organ requirements and enabling donors to share details of organs available for donation. Furthermore, patients could monitor their position on the organ waiting list, enhancing transparency in the process.

6. Conclusions

A detailed analysis of organ donation management systems across various countries, facilitating a deeper grasp of the challenges faced by these systems, has been conducted in this paper. The research concentrated on four research questions, RQ1, RQ2, RQ3, and RQ4. The literature from 50.6% of the publications reviewed in this research explored challenges in organ donation management systems, offering insights into the systems of 30 countries worldwide, to provide an answer to RQ1. The analysis of the literature reviewed to answer RQ1 underscores the predominant concern surrounding organ trafficking, the illicit organ trade, the lack of stakeholder trust in the system, and unethical organ allocation. The primary catalyst for these issues has been the absence of transparency of processes for stakeholders within the organ donation management framework. Furthermore, 12.9% of publications have been reviewed to study the centralized technology-based models developed for managing the system of organ donation, to address RQ2, and 36.5% of publications were reviewed to study the blockchain technology-based decentralized models developed for the same reason, to address RQ3. The response to RQ2 highlights that the centralized technology-based models developed to manage organ donation management systems predominantly employ technologies such as Python, Java, SQL, and Android. Additionally, it has been noted that these models tackle various challenges faced by organ donation management systems. However, due to the centralized architecture of these models, they provide 0% transparency of the processes, thus failing to provide a trustful environment for the stakeholders. Additionally, issues such as organ trafficking, black marketing of organs, and the unethical allocation of organs in the organ donation management systems remain. On the contrary, the analysis of the literature reviewed to answer RQ3 highlights that the blockchain technology-based decentralized models developed for the same reason provide 100% transparency about the entire process to the authorized stakeholders, hence resolving the above-mentioned issues. The findings and observations of RQ4, based on the analysis of the literature reviewed to answer RQ2 and RQ3, establish the superiority of blockchain technology-based decentralized models in resolving problems related to organ donation management systems when compared to centralized technology-based alternatives. In addition to this, the paper provides insights into the current research gaps and future research directions for researchers. The use of competencies of the Internet of Things and artificial intelligence in the domain of organ donation management systems is still in its infancy. Additionally, the use of blockchains beyond Ethereum for the development of a model for managing organ donation systems has been suggested. Furthermore, future research can focus on the development of decentralized applications for enhanced system–user interaction.

Author Contributions: Conceptualization, G.B. and H.S.; methodology, G.B., S.R. and A.K.; validation, G.B., H.S., S.R. and H.M.; formal analysis, G.B., H.S., S.R., A.K. and H.M.; investigation, G.B. and H.S.; resources, H.M.; data curation, G.B., H.S. and S.R.; writing—original draft preparation, G.B. and H.S.; writing—review and editing, G.B., H.S., S.R., A.K. and H.M.; visualization, H.S., S.R., A.K. and H.M.; supervision, S.R. and H.M.; project administration, H.M.; funding acquisition, H.M. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by Institute of Information and communications Technology Planning and Evaluation (IITP) grant funded by the Korea government (MSIT) (RS 2024-00400955, Development of core security technology to respond to international smart ship regulations).

Institutional Review Board Statement: Not applicable for this study.

Informed Consent Statement: Not applicable for this study.

Data Availability Statement: No datasets were generated or analyzed during the current study. Instead, the literature from different publications has been reviewed, and the references for those publications are available in the reference section.

Conflicts of Interest: The authors declare no personal or financial conflicts of interest for this manuscript.

Abbreviations

AI	Artificial Intelligence
ASCII	American Standard Code for Information Interchange
DApp	Decentralized Application
DLT	Distributed Ledger Technology
EHR	Electronic Health Records
EMR	Electric Medical Records
EPTS	Estimated Post-Transplant Survival
ETKAS	Euro-Transplant Kidney Allocation System
IoT	Internet of Things
IPFS	InterPlanetary File System
KAS	Kidney Allocation System
KDPI	Kidney Donor Profile Index
KNN	K-Nearest Neighbor
MORE	Multiple Organ Retrieval and Exchange
MYSQL	My Structured Query Language
NFT	Non-Fungible Tokens
ODMS	Organ Donation Management System
ODP	Organ Donation Platform
OPTN	Organ Procurement and Transplantation Network
PRA	Panel Reactive Antibody
SDK	Software Development Kit
STAR	Standard Transplant Analysis and Research
TPS	Transactions Per Second
UNOS	United Network for Organ Storage
WHO	World Health Organization

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