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Review

Leveraging Industry 4.0 Technologies for Sustainable Humanitarian Supply Chains: Evidence from the Extant Literature

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Abstract: Prevailing and exacerbating impacts of climate change call for robust and resilient humanitarian supply chains (HSCs). To that end, intelligent technologies that brought about the Industry 4.0 (I4.0) revolution, such as the Internet of Things, blockchain, and artificial intelligence, may tremendously impact the optimal design and effective management of HSCs. In this paper, we conduct a systematic literature network analysis and identify trends in I4.0 and HSCs. We posit the need to instill into current HSC efforts the quadruple bottom-line (cultural, economic, environmental, and social) pillars of sustainability and define a Sustainable Humanitarian Supply Chain (SHSC). Based on the extant literature and ongoing practice, we highlight how I4.0 technologies can aid SHSC stages from disaster risk assessment to preparedness to response to relief. The complex nature of SHSCs requires a holistic and multidisciplinary approach and collaboration by scholars, policymakers, and industry practitioners to pool solution resources. We offer future research venues in this fledgling but life-saving scientific discipline. SHSCs can be empowered with I4.0 technologies, a much needed direction in our climate-changed world.

Keywords: climate change; disaster; supply chain and logistics; artificial intelligence; Internet of Things; blockchain; sustainability; risk mitigation; sustainable development; quadruple bottom line

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1. Introduction

Industry 4.0 (I4.0), in essence, is the digitalization and automation of manufacturing and service systems. I4.0 can revolutionize humanitarian supply chains (HSCs) to advance toward sustainability. According to the Director of Innovation and Change Management at the United Nations (UN) World Food Programme (WFP), "Blockchain technology allows us to step up the fight against hunger. Through blockchain, we aim to cut payment costs, better protect beneficiary data, control financial risks, and respond more rapidly in the wake of emergencies. Using blockchain can be a qualitative leap—not only for WFP, but for the entire humanitarian community" [1]. It is widely acknowledged that companies adopting I4.0 technologies, such as blockchain (BkCn), often outperform those that do not [2]. Despite the success of I4.0 technologies in commercial supply chains [3–5], the comparatively slow adoption of these technologies in humanitarian relief operations highlights significant barriers in this domain [6].

Humanitarian supply chains (HSCs) play a pivotal role in disaster relief and management [7–9]. In disaster situations, it becomes challenging to assess the needs of HSCs due to the devastation of infrastructure (roads, ports, airports, warehouses), equipment (helicopters, vehicles), and resources (funds, fuel, labor, management, time, etc.), alongside the evolving situation in affected areas [10]. The difficulties are even more complex, with many players (multiple stakeholders) involved in the relief activities and governmental interventions. Those players and the final beneficiaries are from diverse regions of the world with different cultures [8]. Effective and efficient humanitarian relief operations heavily rely on logistics management, which accounts for about 80% of the total costs related to the disaster response [11].

Climate change is causing more frequent and intense weather-related disasters. These disasters disrupt supply chains and the world, resulting in many displaced persons (refugees). In 2022 alone, refugees from disasters reached 60.9 million (32.6 million due to natural disasters and 28.3 million due to human-made disasters), marking an increase of over 60% compared to 2021 [12]. HSCs are crucial for effective responses, providing relief such as food, water, shelter, and medical supplies to those in need. As the increasing trend of disasters and refugees due to the impacts of climate change will likely continue in the future [13], the role of HSCs in disaster response, recovery, and relief efforts for supporting communities in need is critical [14,15].

Furthermore, significant humanitarian crises, exemplified by the protracted refugee situations in countries like Syria and its neighboring nations—Lebanon and Türkiye, each hosting over a million refugees—and the COVID-19 global pandemic underscore the urgent need for sustainable solutions [16,17]. With the escalation of disasters and the swift rise in refugee numbers, the scope of relief initiatives broadens, imposing substantial demands on engaged organizations. Hence, integrating I4.0 technologies may become pivotal in relieving this mounting pressure [18].

Given the preceding uncertainties, there is an urgent need for scarce resources within the high-demand context of humanitarian logistics [6,19]. Thus, I4.0 technologies (e.g., Internet of Things (IoT), big data analytics (BDA), artificial intelligence (AI) and machine learning (ML), BkCn, cloud computing, and robotics) can significantly bolster HSCs [20,21]. These technologies have showcased potential benefits for HSCs.

Examples include utilizing BDA to analyze disaster-generated data for decision making [5,22] and enhance visibility and coordination [6]. BkCn has enhanced collaboration during disaster relief [23,24]. Automated robotics was employed for emergency response during the Fukushima Daiichi nuclear power incident [25]. Overall, these technologies showcase the potential of Industry 4.0 in HSCs, mitigating disaster risks and lessening uncertainties in humanitarian operations.

Moreover, integrating I4.0 may enhance operational efficiency and impact donors' behavior in humanitarian aid operations [26,27]. I4.0 technological advancements, particularly in the security and transparency of transactions with BkCn, can influence the decision to donate and the choice of items to donate. While some research has explored potential barriers and interactions in implementing I4.0 technologies [6,28], there is still a significant research gap in understanding how humanitarian actors can effectively and efficiently implement these technologies and under what conditions.

Therefore, our paper aims to help comprehensively understand HSCs for successfully adapting I4.0 technologies. Using intelligent technologies in HSCs results in a more efficient, effective, and sustainable approach to humanitarian action, known as Sustainable Humanitarian Supply Chains (SHSC), ultimately aiding those in need. However, relatively few contributions have focused on the need for SHSCs due to natural disasters as a result of climate change. Hence, we attempt to define SHSCs and delve into SHSCs and their integration with I4.0 technologies aimed at mitigating risks linked to climate change and uncertainties in HSCs.

Furthermore, many scholars agree that adopting I4.0 technologies can support HSCs [21] and contribute to achieving the UN's sustainable development goals [29]. Hence, we hope to demonstrate further that I4.0 technology in HSCs has significantly saved numerous lives and properties [30]. Thus, we aim to address the following research questions (RQs):

RQ1: What does the extant literature say about SHSCs, I4.0, and climate change?
RQ2: How can I4.0 technologies support SHSCs in the face of climate crises?
RQ3: What are the current barriers and enablers for I4.0 integration into SHSCs?
RQ4: What are the sustainability considerations in using I4.0 in SHSCs?

The layout of this paper is as follows: Section 1 introduces the topic, while Section 2 focuses on the research motivation, background, and questions. Section 3 presents the extant literature's methodology, results, and trend analysis. Section 4 delineates barriers and trends for integrating emerging I4.0 technologies into SHSCs. This paper concludes in Section 5 with potential future research venues and final remarks.

2. Research Background and Questions

2.1. Background

2.1.1. Humanitarian Supply Chains and Disaster Management in Climate Crises

Natural and human-made disasters pose a significant risk to society and are increasing year by year throughout the world. The UN Office for Disaster Risk Reduction estimated that direct economic losses from these disasters globally amounted to approximately USD 2.0 trillion from 1998 to 2017 [31]. Furthermore, projections suggest that the annual number of medium- to large-scale disaster events could reach 560 by 2030, averaging 1.5 events per day—a 40% increase from 2015 [29].

HSCs are pivotal in disaster management, operational activities, and administrative decisions related to various disasters at all levels [32]. This is particularly crucial as HSCs operate under compromised infrastructural conditions, such as limited energy resources and diminished transport connectivity. An HSC collaborates with multiple stakeholders involved in relief activities, governmental interventions, and the final beneficiaries. In addition, HSCs contribute significantly to achieving efficient and prompt responses to natural and human-made disasters [33]. The rising trend of disasters, exacerbated by climate change, adds enormous pressure to HSCs. This has, therefore, led to discussions on the concept of sustainability in the role of HSCs in disaster management.

Most recently, the pandemic has spotlighted supply chain vulnerability, emphasizing the need for sustainability. COVID-19 notably disrupted supply chains, impacting health, the economy, and society [34,35]. Compared to other disasters, managing HSCs during COVID-19 presented distinct challenges [36]. Ivanov and Dolgui [18] proposed that Industry 4.0 could have mitigated COVID-19-related supply chain risks. Additionally, Shrivastav and Bag [21] proposed "humanitarian supply chain management in the digital age", highlighting the use of I4.0 technologies to mitigate risks associated with climate change and uncertainties in HSCs.

2.1.2. Industry 4.0 and Its Implementations in HSCs

I4.0 can be defined as "[. . .] integrity of technologies, organizational concepts, and management principles underlying a cost-efficient, responsive, resilient and sustainable network, data-driven and dynamically and structurally adaptable to changes in the demand and supply environment through rapid rearrangement and reallocation of its components and capabilities" [37], p. 2056.

I4.0 represents the fourth industrial revolution, characterized by the introduction of advanced technologies (i.e., the IoT, BDA, AI, ML, BkCn, cloud computing, and Internet of services concepts) into the manufacturing and service industries. It is defined as integrating these modern technologies to achieve automation and, thus, better control manufacturing. One of the main features of I4.0 is the use of information and new technologies to support the integration and virtualization of manufacturing design and production processes, thereby gaining a competitive advantage.

Many scholars are convinced that the preceding tools of I4.0, such as IoT, AI and ML, BDA, and BkCn, can support HSC resilience and call for research in this area. For instance, leveraging BDA to analyze the extensive data generated by people during disasters has proven invaluable in better decision making and reducing vulnerabilities [5,22].

Dubey et al. [6] demonstrated that BDA significantly enhances visibility and coordination within HSCs, improving overall performance. BkCn technology can enhance collaboration for relief operations amidst disaster situations [24,38]. The International Federation of the Red Cross markedly improved the efficiency of relief operations by implementing innovative traceability through adapted information systems, recognized by the prestigious "European Supply Chain Excellence Award" [39].

Automated robotics aided in the emergency response at the Fukushima Daiichi Nuclear Power Plant in 2011 amidst radiation constraints [25]. Shrivastav and Bag [21] proposed the topic "Digital-enabled risk reduction for climate changes and uncertainty" in HSC management (HSCM), emphasizing the use of digital technology to mitigate risks associated with climate change and uncertainties in humanitarian operations. This enables early risk identification, establishment of early warning systems, resilient infrastructure development, data-driven decision making, and enhanced stakeholder cooperation. Therefore, we investigate how this approach enables enhanced supply chain resilience and effectiveness in mitigating the impacts of climate change.

2.1.3. The Need for Sustainable Humanitarian Supply Chains

Given the escalating frequency of disasters in recent years, these emergencies will last a long time, and the pressing need for sustainable HSCs remains an issue [40].

Table 1 compares goals, logistic approaches, time horizons, solutions, and so on for commercial SCs (CSCs), HSCs, and SHSCs. A traditional supply chain is designed to deliver the desired goods and materials to the right customers at the correct time. An HSC is a complex network guided by non-profit motives, distinguishing it from commercial SCs. Further attributes separating HSCs from commercial supply chains include reactive and temporary set-up logistics in disaster response, requiring three main planning components (preparedness, response, and collaboration). Rapid disaster response necessitates early resource mapping and the acquisition of significant assets adapted to deployment conditions [41].

Table 1. Comparisons among commercial SCs, HSCs, and SHSCs.

Aspect	Commercial SCs	Humanitarian SCs	Sustainable Humanitarian SCs
Goal	Profit	Non-profit, rapid delivery of emergency relief during crises.	Rapid delivery of emergency relief with a focus on long-term sustainability.
Logistics Approach	Proactive and reactive	Primarily reactive.	Proactive and reactive.
Time Horizon		Ad hoc, short-term focus on immediate response.	Extends focus to long-term planning and recovery.
Solution	Quality, cost, time, risk	Data-driven, multi-objective, goal programming, real-time.	Agility, adaptability, and alignment.
Resource Efficiency		Focuses on efficient resource allocation for swift aid.	Optimizes resource use for both immediate and long-term aid efficiently.
Community and Cultural Integration		Considers community needs but may not deeply integrate cultures.	Integrates cultural understanding and practices for effective aid delivery.
Environmental Responsibility		Acknowledges environmental challenges but not the primary concern.	Actively seeks to minimize environmental impact and waste reduction.
Adaptability and Innovation		Focuses on immediate aid, may need more emphasis on adaptability.	Encourages innovation and adaptability to enhance aid effectiveness.

CSCs and HSCs are guided by "sustainable development", which is defined as "meeting the needs of the present generations without compromising the ability of future generations to meet their own needs" [42], particularly in response to the heightened risk of disasters due to climate change [29,40,43,44]. Van Wassenhove [10] emphasizes that SHSCs must have core competencies, being agile, adaptable, and aligned. SHSCs extend their time horizon, emphasizing long-term planning, reclamation, and reconstruction efforts to achieve sustainable outcomes that aid in the recovery and re-development of affected regions.

While an HSC aims to rapidly deliver aid to save lives and mitigate suffering during crises, an SHSC also emphasizes the long-term sustainability of the operations and the chain itself. Lee [45] integrates three properties (agility, adaptability, alignment) that integrate environmental considerations with resource efficiency to harmonize with local communities and cultures for enduring positive impacts. Therefore, SHSCs actively incorporate environmental considerations to minimize adverse environmental impacts by optimizing logistics and distribution methods, reducing waste, and promoting eco-friendly practices.

HSC organizations operate in increasingly complex and dynamic contexts in the current global environment. Yun and Ülkü [13] assert that a sustainable supply chain becomes inevitable in meeting the drastic changes in climate and crises.

While the role of culture has been an essential construct in the design of successful supply chains, research exploring the impact of culture on the success of HSCs is scarce [13,40]. As shown in Figure 1, the quadruple bottom-line (QBL) pillars—encompassing economic, social, environmental, and cultural factors [46]—provide a comprehensive framework for sustainable HSCs.

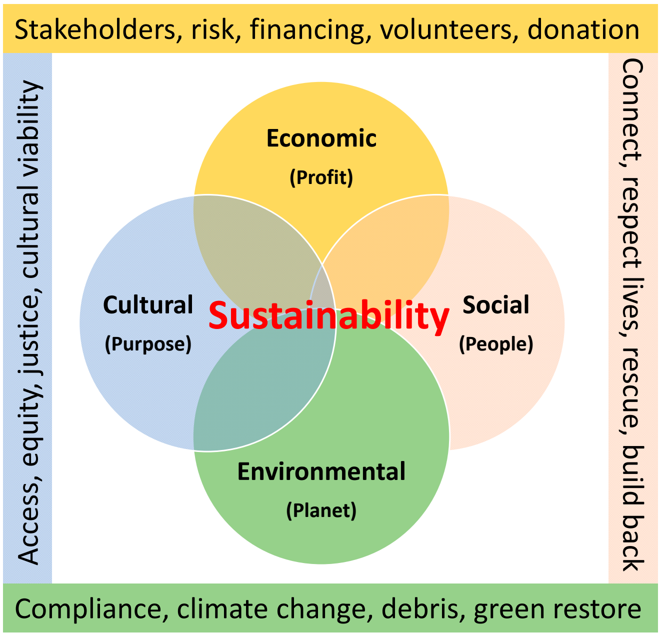


Figure 1. Summary of the QBL pillars for HSCs.

I4.0 technologies can be integrated into SHSCs to enhance efficiency, visibility, and responsiveness. Because efficient relief operations face significant challenges (i.e., particularly in swiftly establishing trust and coordination), applying I4.0 technologies can be a promising solution to enhance trust and coordination in relief operations [20,21]. In addition, sustainability requires that one find appropriate mitigation responses to the increasingly complex systems of relief operations.

Recently, the United Nations outlined the sustainable development goals (SDGs) as a global objective to foster prosperity for people and the planet through collaborative efforts among nations. In this context, SHSCs can contribute to meeting several SDGs, including SDG#2 (Zero Hunger), SDG#3 (Good Health and Wellbeing), SDG#11 (Sustainable Cities and Communities), and Climate Action (SDG#13). We adopt a disaster management stream in SHSCs, divided into risk assessment, preparedness, immediate response, and ongoing recovery and relief, as illustrated in Figure 2 (see [47]). We assert that I4.0 technologies can enhance performance for all these phases of HSC.

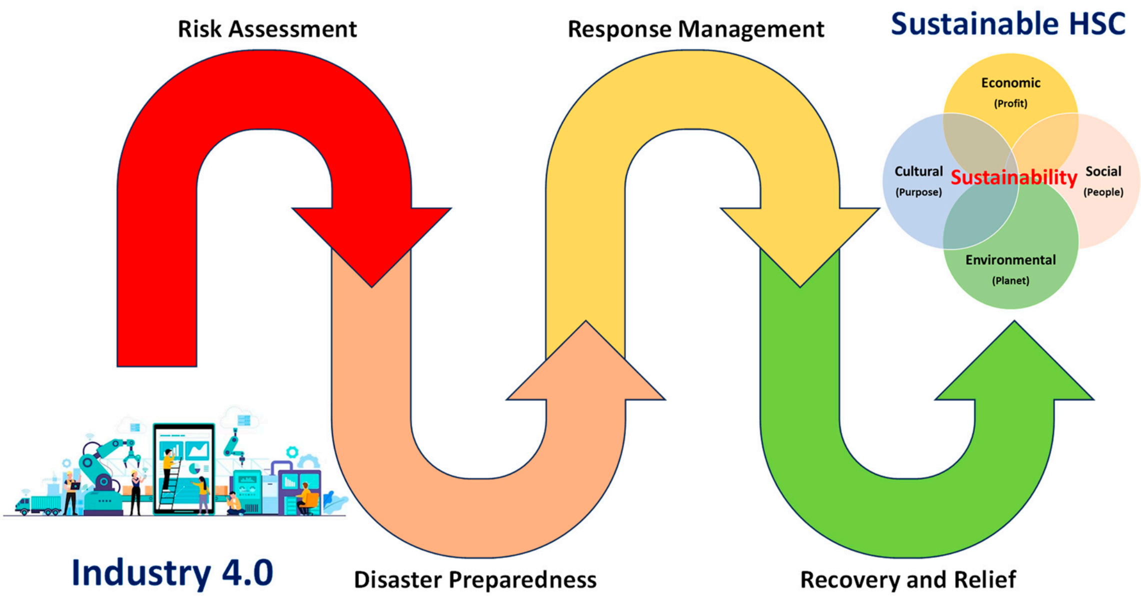


Figure 2. Depiction of the phases of a Sustainable Humanitarian Supply Chain.

Pervasive technologies can significantly enhance an SHSC's objectives. Integrating SHSCs with predictive capabilities enables early disaster anticipation and improved responsiveness [48], ultimately reducing fatality rates. Therefore, a comprehensive study is essential to understand the integration of I4.0 technology into SHSCs. The aim is to account for economic, environmental, social, and cultural factors and give sustainability paramount importance. Adopting the QBL sustainability pillars for SHSCs, as proposed by Oguntola and Ülkü [47], becomes crucial. Several papers emphasize how social considerations, including data privacy, bias, fairness in decision making [49], and cultural identities and practices (religious beliefs, customs) are integrated into HSCs using I4.0 technologies during disasters. AI, one of the I4.0 technologies, can potentially enhance SHSC efficiencies aligning with the QBL sustainability principles [47]. Big data is produced by collecting data (enhanced with I4.0 technologies) and predicting future humanitarian needs. Using big data for better decision making must be sustainably developed and implemented [50–52]. Table 2 displays key papers that specifically relate to two or more QBL aspects of HSCs.

Table 2. Select Papers with QBL sustainability pillars in HSCs.

Papers	Economical	Environmental	Societal	Cultural
Ivanov and Dolgui [18]	√	√		
Laguna-Salvadó et al. [33]	√	√	√	
Karl and Scholz [42]	√	√	√	
Oguntola and Ülkü [47]	√	√	√	√

Motivated by the preceding discussions, we define an SHSC as the viable integration and timely and effective coordination of humanitarian aid organizations, civic groups, specialized task forces, governments, and first aid responders to design and implement all humanitarian logistics systems and operations. The goal is to save as many lives as possible (societal) at the least cost possible (economical) while reducing the impact of disasters on the environment (e.g., reducing hazardous debris) and ensuring the conservation of and equitable response to culturally distinct communities.

2.2. Research Motivation

To enhance the motivation for our research, we identified potential journals that had published articles related to Industry 4.0, HSCs or humanitarian logistics, climate change and disaster, and sustainability. We classified the articles identified based on (1) HSC and disaster management, (2) climate change and HSC, (3) Industry 4.0 and humanitarian or disaster, and (4) Industry 4.0 and HSC and sustainability.

Figures 3 and 4 illustrate the trends in the overarching themes we delve into within this study. This search was conducted in Scopus on 10 January 2024, focusing exclusively on scholarly works (English articles) from the past two decades (2003–2023) in four-year sub-periods.

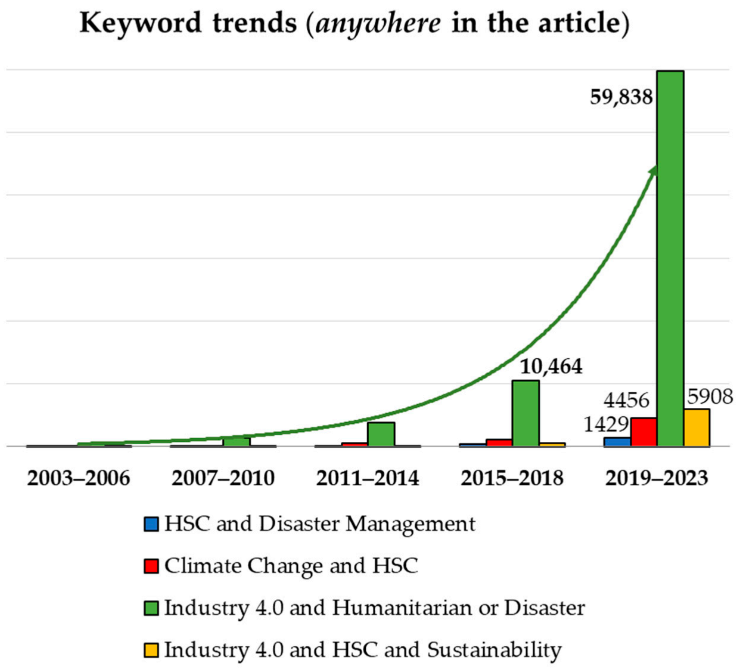


Figure 3. Keyword trends (anywhere in the article) for searches (2003–2023).

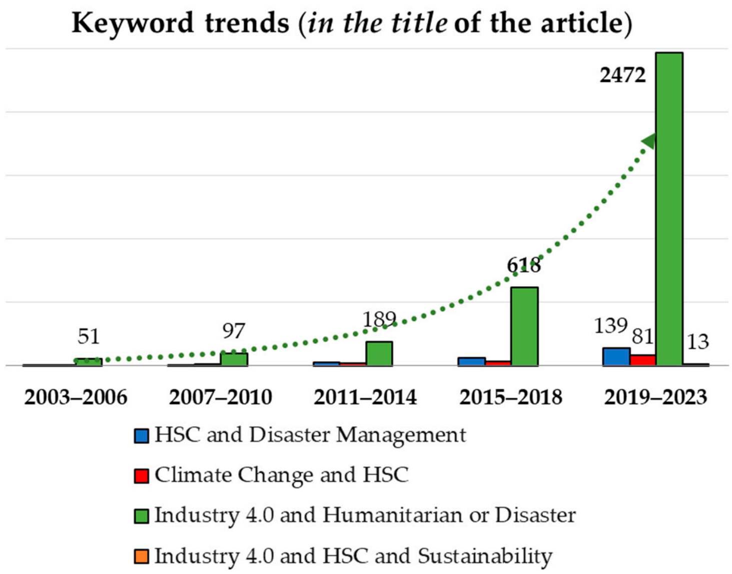


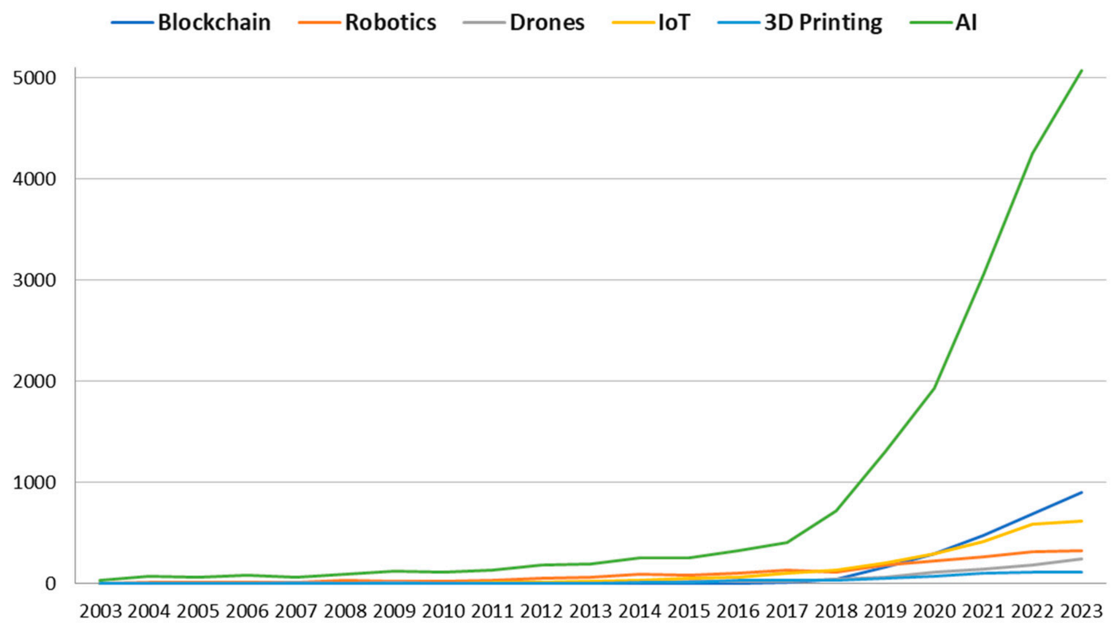
Figure 4. Keyword trends (in the article's title) for searches (2003–2023).

In Figure 3, which considers the search terms ”anywhere in the article”, a clear upward trend is observed in research on I4.0, HSCs, disaster, and climate change. Notably, there is an increasing focus on climate change within the HSC field and the application of I4.0 in HSCs within the context of disasters. For instance, from 2019 to 2023, approximately 60,000 scholarly works included the term ”I4.0”, encompassing technologies such as AI and BkCn, in conjunction with terms ”humanitarian” and ”disaster”. A closer analysis revealed that about 7700 articles specifically mentioned ”COVID” (4470 in 2022, 2560 in 2021, and 675 in 2020), underscoring the substantial impact of the COVID-19 pandemic and the active consideration of I4.0 technologies.

On the other hand, Figure 4 offers a more focused perspective, considering scholarly works where the search terms were explicitly present in the articles’ titles and abstracts. During the 2019–2023 period, when these terms first emerged, a few works included the terms “I4.0”, “HSC”, and “Sustainability” or “sustainable” [28,53–57].

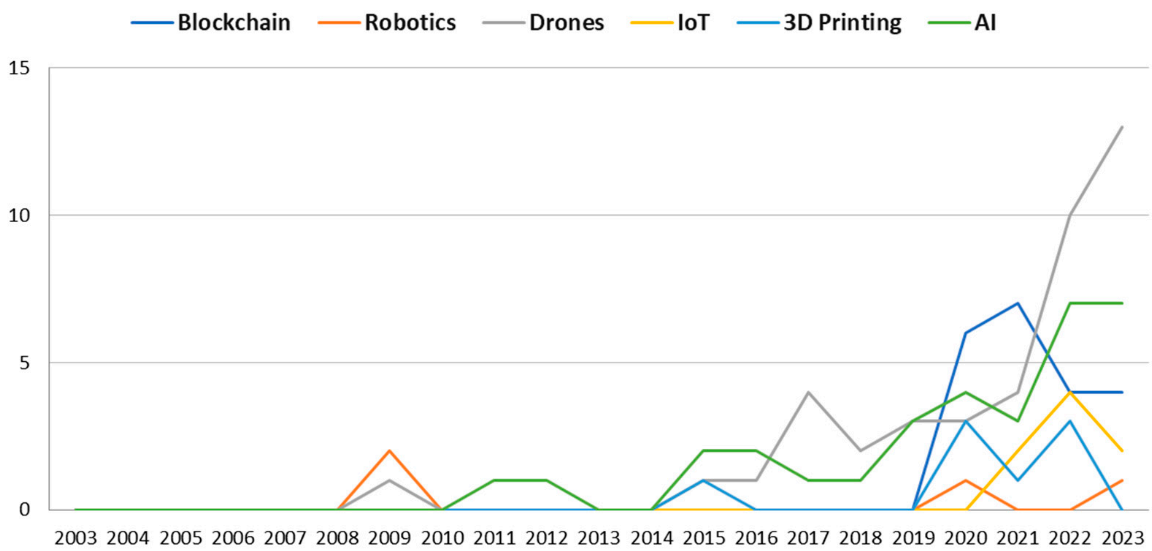
Furthermore, hardly any articles have addressed the need for I4.0 in sustainable HSCs during climate change-induced disasters ([55] being an exception). This indicates a relatively limited body of literature studying this intersection. Therefore, an integrated approach is crucial for comprehensive research on I4.0, HSCs, and sustainability, given the evolving dynamics and growing challenges, particularly from the impacts of climate change in these areas.

Figure 5a,b illustrates the number of papers incorporating I4.0 technologies in SCs and HSCs in their titles and abstracts, depicting the trends of publications on Scopus from 2003 to 2023. Our paper responds to the proposal by Frederico et al. [58]: We consider a broader range of I4.0 technologies such as BkCn, AI, robotics, drones, IoT, and 3D printing (3DP) in SCs and HSCs. We first note that research on I4.0 and SCs is overwhelmingly (and plausibly) higher than that of HSCs. Articles about AI in the HSC domain showcased a steady rise, dominant in popularity, with a sharp increase in 2020. Research in the HSC field for I4.0 technologies other than AI is also rising. Notably, BkCn exhibited a significant increase.



(**a**) I4.0 Technologies and supply chains

Figure 5. *Cont.*



(**b**) I4.0 technologies and humanitarian supply chains

Figure 5. Publication trends on I4.0 technologies in (**a**) SCs and (**b**) HSCs (2003–2023).

Similarly, IoT has shown a consistent rise over the years. These trends indicate the continued recognition of the importance and potential of I4.0 technologies in the HSC domain. Thus, we aim to explore how these I4.0 technologies are being proposed and applied. By mapping out scenarios where those technologies can be implemented in disaster management, we may influence the planning and implementation of agile HSCs.

AI is the dominant I4.0 technology in SC research, followed by BkCn and IoT. However, in HSC research, the drone is the leading I4.0 technology, followed by AI and BkCn.

2.3. Research Questions

In this study, we delve into the role of I4.0 technologies in enhancing SHSCs in disaster management within the context of climate change. Below, our research objectives are aligned with the research questions introduced in Section 1.

For RQ1, there are relatively few contributions; we address the need for SHSCs to mitigate natural disasters resulting from climate change. We attempt to define SHSCs and explore their integration with I4.0 technologies to mitigate climate change-related risks and uncertainties in HSCs (Section 3). We also investigate how these advancements can be applied to SHSCs in a world impacted by climate change and shaped by the digital era.

As for RQ2, we broaden our investigation to include various I4.0 technologies such as BkCn, AI, robotics, drones, IoT, and 3DP in HSCs (c.f., [58]). We aim to assess the potential benefits and efficiencies that I4.0 technologies can bring to HSCs, particularly in disaster management and risk reduction associated with climate change. We explore specific transformations enabled by I4.0 and how they can respond to SHSCs' sustainability needs.

However, implementing SHSCs in disaster and crisis scenarios presents significant challenges due to constraints on time and resources. This necessitates the active adoption of integrated I4.0 technologies (presuming it will help the viable incorporation of timely and effective coordination of humanitarian aid organizations) for effective management and harmonization of humanitarian aid agencies. Few studies have focused on the synchronization of I4.0 technologies into SHSCs. We address RQ3 by examining the current barriers and enablers for I4.0's integration into SHSCs.

Lastly, we address RQ4, which aligns with the QBL sustainability pillars in SHSCs (c.f., [47]). Our study explores the essential social and cultural considerations when integrating I4.0 technologies into SHSCs to address climate change-induced disasters.

3. Methodology and Results

3.1. Systematic Literature Network Analysis

This study employs systematic literature network analysis (SLNA), integrating an organized literature review with bibliometric network analyses [13,59,60]. Figure 6 illustrates the SLNA process utilizing multidisciplinary academic databases.

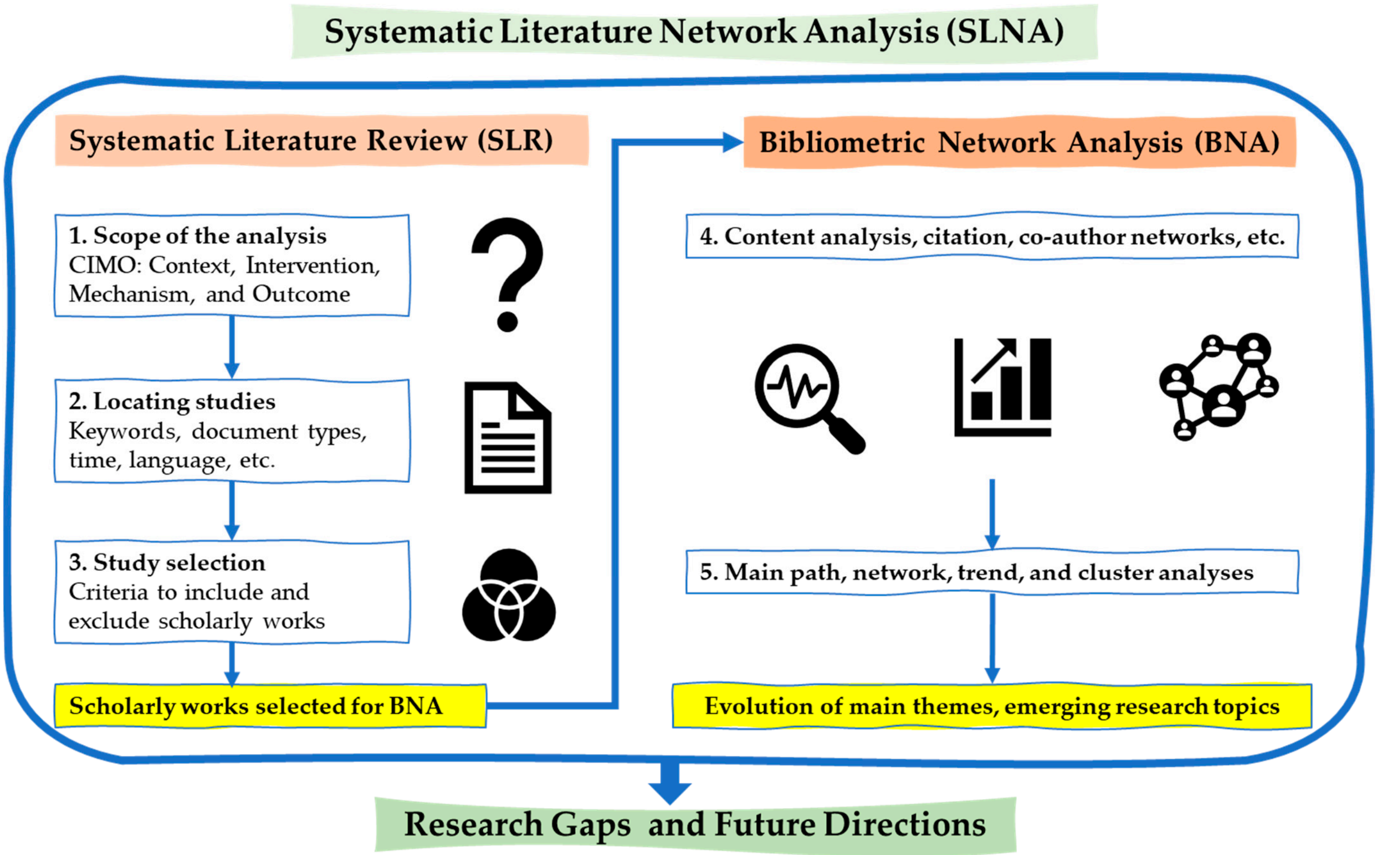


Figure 6. The SLNA framework [13].

We performed a focused, systematic literature review on peer-reviewed papers to discern patterns and pinpoint gaps in current scientific publications. We used specific keywords in our search for enhanced relevance, targeting I4.0 technologies integrated into SHSCs to address climate change-induced disasters. We included synonymous expressions for the keywords. Scopus, a reputable academic database, is utilized for its capacity to rank and cite high-quality peer-reviewed articles [61]. Scopus is a well-recognized tool for data source screening, known to produce reasonably comprehensive results. Therefore, we searched peer-reviewed articles written in English published from 2003 to 2022 within 13 reputable journals—Annals of Operations Research, Business Strategy and the Environment, European Journal of Operational Research, International Journal of Climate Change Strategies and Management, International Journal of Disaster and Risk Management, International Journal of Physical Distribution and Logistics Management, International Journal of Production Economics, International Journal of Risk Assessment and Management, Journal of Cleaner Production, Journal of Humanitarian Logistics and Supply Chain Management, Science of the Total Environment, Sustainability, and Transportation Research Part E: Logistics and Transportation Review. To identify relevant articles, we employed keywords encompassing humanitarian logistics and supply chains, sustainable HSCs, HSC alignment, adaptability and agility, climate change and disaster, and implementation of I4.0 technologies in HSCs. The list of narrowed-down references was visually checked for possible redundancy and irrelevance.

3.2. Results

As shown in Table 3, articles in the preceding journals were categorized into four groups: (1) HSCs, (2) climate change and disaster, (3) I4.0 technologies, and (4) SHSCs. The highest number of papers are related to climate change and disaster, indicating strong research attention and recognition of the importance of addressing climate change and disaster-related issues. Also, a substantial amount of research is focused on I4.0 technologies, showing a significant interest and emphasis on integrating and applying Industry 4.0 technologies in various domains.

Table 3. Categorization of journals and the number of related articles.

Title of Journals (Total Number of Articles)	HSC (148)	Climate Change and Disaster (576)	I4.0 Tech (543)	SHSC (12)	Journal Total (1279)
Sustainability	5	228	360	2	595
Int. J. Disaster Risk Reduct.	11	198	0	0	209
Sci. Total Environ.	0	95	11	0	106
J. Cleaner Prod.	0	24	80	1	105
J. Humanit. Logist. Supply Chain Manag.	85	0	0	5	90
Int. J. Prod. Econ.	9	1	52	1	63
Ann. Oper. Res.	16	0	19	3	38
Int. J. Clim. Change Strategies Manag.	0	30	0	0	30
Bus. Strategy Environ.	0	0	21	0	21
Transp. Res. Part E Logist. Transp. Rev.	7	0	0	0	7
Eur. J. Oper. Res.	6	0	0	0	6
Int. J. Phys. Distrib. Logist. Manag.	5	0	0	0	5
Int. J. Risk Assess Manag.	4	0	0	0	4

While contributions from the HSC research community are on the rise, a limited number of articles explicitly focusing on SHSCs exist. These articles [5,33,40,42,62–67] address various aspects of SHSCs.

Those aspects involve defining and proposing a framework for HSCs [40,62], coordination [63,68], highlighting the unique characteristics of SHSCs [33], exploring the role of BDA [5,69], discussing lean management principles [65,70], and responding to contemporary challenges such as the COVID-19 pandemic [36]. Most articles are literature or theoretical reviews; the few empirical or case studies include [5,62,64,67].

3.2.1. Publication Years

As shown in Figure 7, the number of articles per year related to HSCs across the selected journals remained relatively low in earlier years but has shown a gradual increase over time, with a peak in 2022. This suggests a growing interest in this field. In contrast, papers on climate change and disasters remained minimal in number initially but surged significantly in 2015, likely due to the Paris Agreement signed that year [13]. Articles related to I4.0 have slowly increased, with a rapid jump in 2020. However, publications addressing SHSC have generally remained scarce, emphasizing the need for further research. In Section 4, we delve into the annual trends in more detail.

Table 4 shows the recent research trends according to the most cited articles in the field of HSCs and highlights the I4.0 technologies involved, ordered by the highest number of citations as of October 25, 2023. Ali and Kannan [55] conducted a literature review using topic modeling to analyze healthcare operations and supply chain management research. Popular research topics in this area include the COVID-19 pandemic, I4.0 technologies, sustainability, risk and resilience, climate change, circular economy, humanitarian logistics, behavioral operations, service ecosystem, and knowledge management. Shayganmehr et al. [20] focused on applying I4.0 to improve coordination and trust within HSCs to respond to disasters effectively. They recommended investing in I4.0 enablers such as IoT and BDA to enhance HSC performance for its sustainability. Saldanha-da-Gama [71] provides a broader perspective on the enduring relationship between facility location, logistics, and transportation, discussing their interconnectedness and current challenges. Akbari et al. [72] propose an algorithm to restore damaged roads post-disaster.

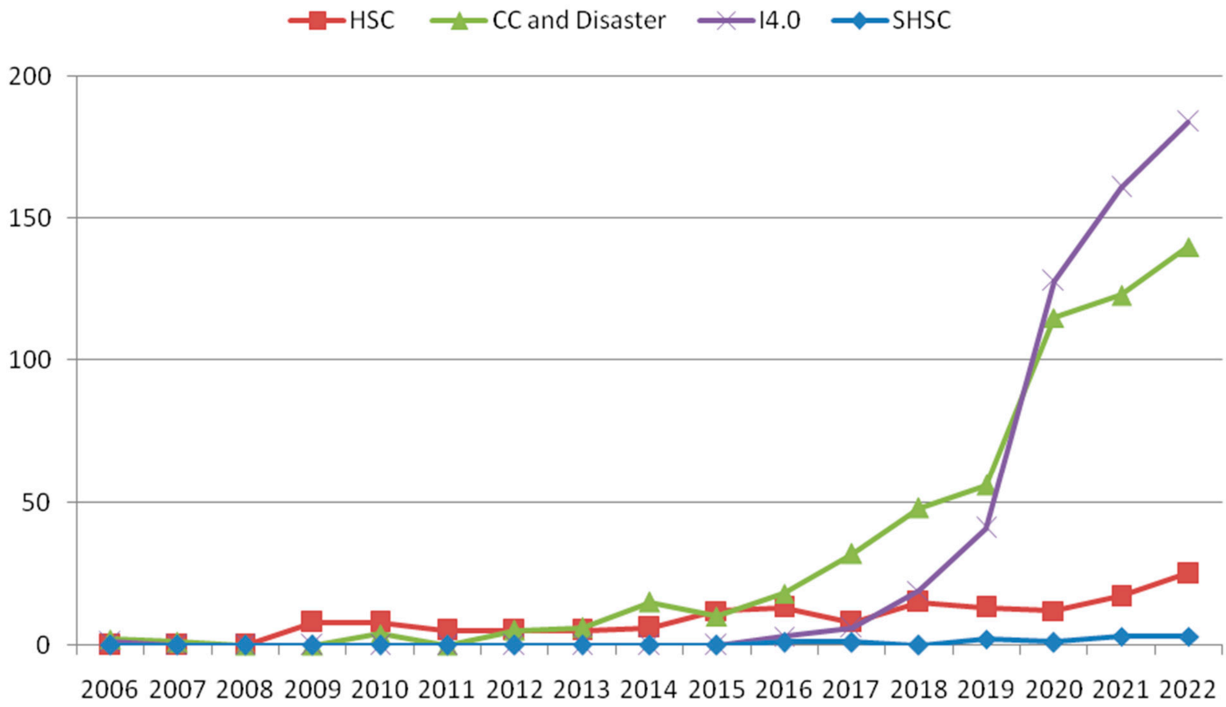


Figure 7. The number of articles related to HSCs, CC and disasters, I4.0, and SHSCs within targeted journals (2003–2022).

Table 4. The most cited (by December 2023) articles in the HSC and I4.0 technology field.

Document Title	Author(s)	Journal	Year	Citations
Mapping research on healthcare operations and supply chain management: a topic modelling-based literature review [55]	Ali and Kannan	Annals of Operations Research	2022	37
Assessing the role of industry 4.0 for enhancing swift trust and coordination in humanitarian supply chain [20]	Shayganmehr, Gupta, Laguir, Stekelorum, and Kumar	Annals of Operations Research	2021	12
Facility location in logistics and transportation: An enduring relationship [71]	Saldanha-da-Gama	Transportation Research Part E: Logistics and Transportation Review	2022	10

3.2.2. Top Publishing Countries

Figure 8 illustrates the leading contributors regarding the total number of articles. China emerges at the forefront with the highest total number of papers (186), followed closely by the United States (164) and the United Kingdom (138). In the realm of HSCs, the United States takes the lead with the highest number of articles, followed by the United Kingdom and France. For climate change and disaster, China leads the pack with the most publications on this subject (119), followed by the United States and the United Kingdom. China stands out again in the domain of I4.0 technologies, boasting the highest number of articles related to this area (66), followed by the United Kingdom and Italy. Lastly, in terms of the SHSC field, India takes the lead, followed by the United States.

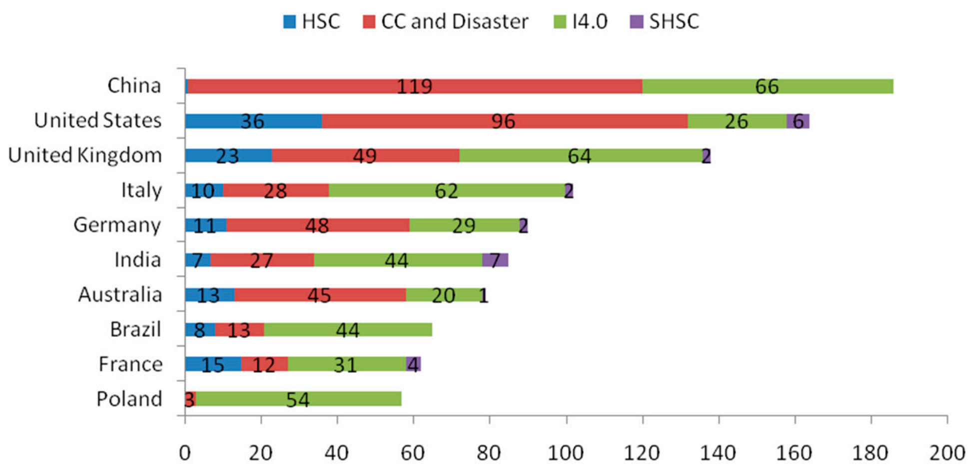


Figure 8. Top publishing countries across articles related to HSCs, CC and disasters, I4.0, and SHSCs (2003–2022).

3.3. Trend Analysis Based on the Extant Literature

NVivo is qualitative data analysis software [73,74] for extracting insights from unstructured data like text, audio, video, and images. "Word clouds" visualize word frequency in the data, where larger words appear more frequently. Researchers can uncover key themes and relationships within the content by assessing these word clouds. Prominence in word cloud layout is purely aesthetic and has no inherent meaning. Researchers often use attributes like bold, large, or red text to emphasize important terms or concepts. The word cloud (generated in NVivo 14) shows word associations and connections, which can be determined by observing the word cloud, as the proximity or co-occurrence of words suggests themes or associations within the data. These terms relate to I4.0 technologies, HSCs, SHSCs, and the context of climate change. We query the final articles' titles and abstracts from the last two decades, 2003–2022, in Table 2.

The cloud in Figure 9 provides a comprehensive view of the central themes and areas of research within the field of HSCs and related topics over the past two decades. Researchers have delved into a diverse array of topics, encompassing disaster management, sustainability practices, technology integration, and resilience strategies, all aimed at enhancing the efficiency and effectiveness of HSCs. In a detailed examination, the prominence of specific keywords signifies the primary focus areas. Notably, red-colored, large-font words such as research, disaster, industry, model, risk, and management stand out.

Subsequently, critical keywords, in black and medium-sized fonts, include humanitarian, supply, chain, technology, climate, sustainable, development, system, design, related, flood, data, increase, areas, and making. Furthermore, smaller black words, such as social challenges, decision, limited, logistic, implementation, reduction, process, resilience, implications, performance, response, digital, key, level, policy, natural, reduction, analysis, proposed, and assessment, complement the central themes. The multifaceted nature of these keywords underscores the intricate and consequential landscape of this field of study. Researchers have probed various dimensions to drive innovation and address the complexity of HSCs.

The central and most prominent node, marked as a large red circle in Figure 10, is "humanitarian", closely connected to the second largest red circle, "logistics". "Humanitarian" is linked to key concepts such as "disaster relief", "coordination", "disaster management", and "agility", represented as smaller red circles. Additionally, "humanitarian" is connected to "supply chain management", presented as a medium-sized green circle that further extends to smaller green circles, including "HSC", "disasters", and "aid agencies". "Humanitarian" is also associated with "disaster relief operations" and "emergency logistics", illustrated as small blue-colored circles. Lastly, "humanitarian" maintains connections to "sustainability" and "supply chain", depicted as small yellow-colored circles. Figure 10, thus, emphasizes the crucial roles of humanitarian activities, logistics, disaster management, supply chain management, and sustainability in this research domain.

Figure 9. NVivo's word cloud: text-mined keywords for 2003–2022.

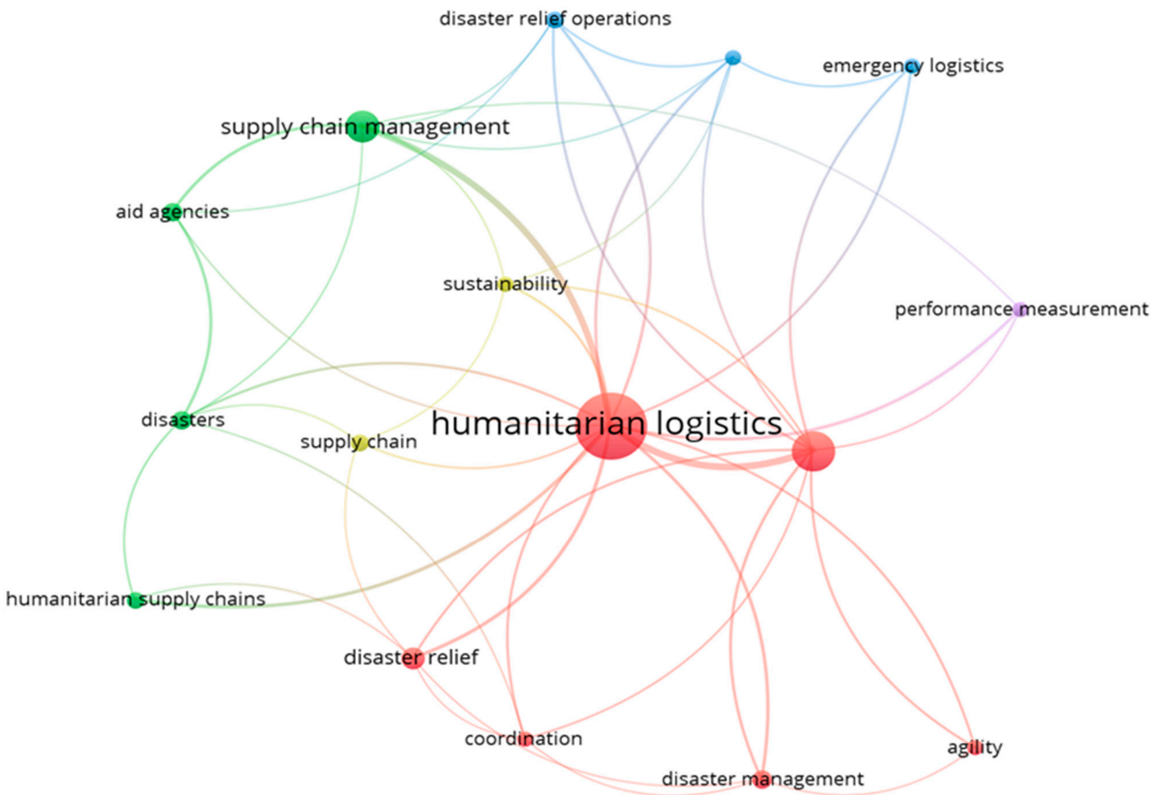


Figure 10. Humanitarian supply chain via VOSviewer (version 1.6.20).

The central and most prominent node in Figure 11, marked as a large yellow circle, is "Industry 4.0", closely connected to the second largest red circle, "sustainability". "Industry 4.0" is intricately linked to essential concepts such as "digitalization", "digital transformation", "big data", "machine learning", and "AI", creating a network of interrelated research areas. Notably, Industry 4.0 has recently developed connections to emerging topics such as "sustainable development goals (SDGs)", "innovation", and "COVID-19". We see that Figure 11 provides a visual representation of the central themes and evolving relationships within the I4.0 field, highlighting the critical intersection of Industry 4.0 technologies with sustainability, digitalization, and pressing global issues.

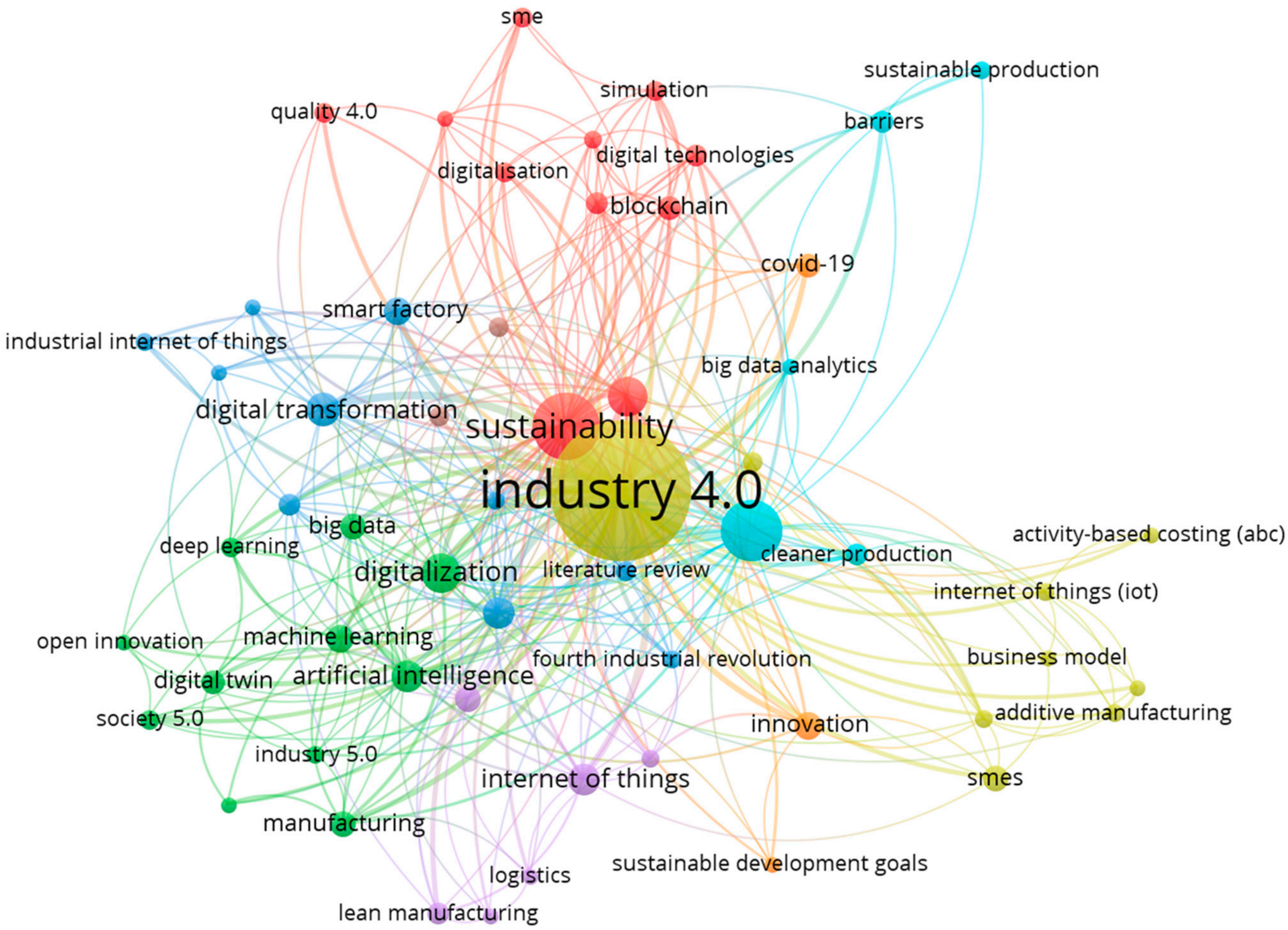


Figure 11. Industry 4.0 via VOSviewer.

In Figure 12, marked as a large green circle, is the central and most prominent node, "climate change". It connects closely to the second largest circles of "resilience" and "adaptation". "Climate change" is intricately linked to a range of critical concepts, including "sustainability", "adaptive capacity", "disaster preparedness", "natural hazards", "risk assessment", "risk management", "social vulnerability", "transformation", "policy", "urban planning", "food security", "drought", "China", "floods", and "urban resilience".

Figure 13 highlights the critical focus on building resilience, adapting to changing conditions, and addressing various climate-related challenges. The central and most prominent node, marked as a large green circle, is "sustainability", which is closely connected to the second largest circle, "HSC". These two circles are linked to "humanitarian logistics", depicted as circles of the same size as "HSC", with "sustainability" slightly closer to it.

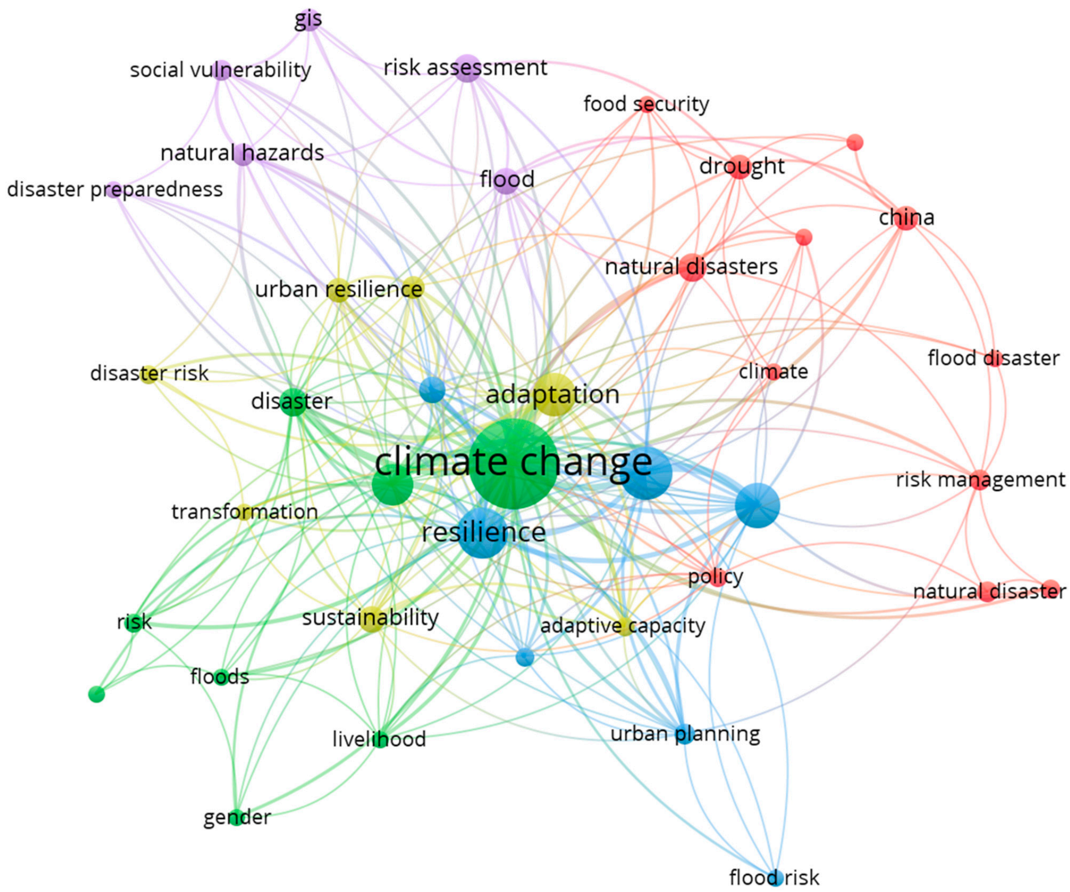


Figure 12. Climate change and disasters via VOSviewer.

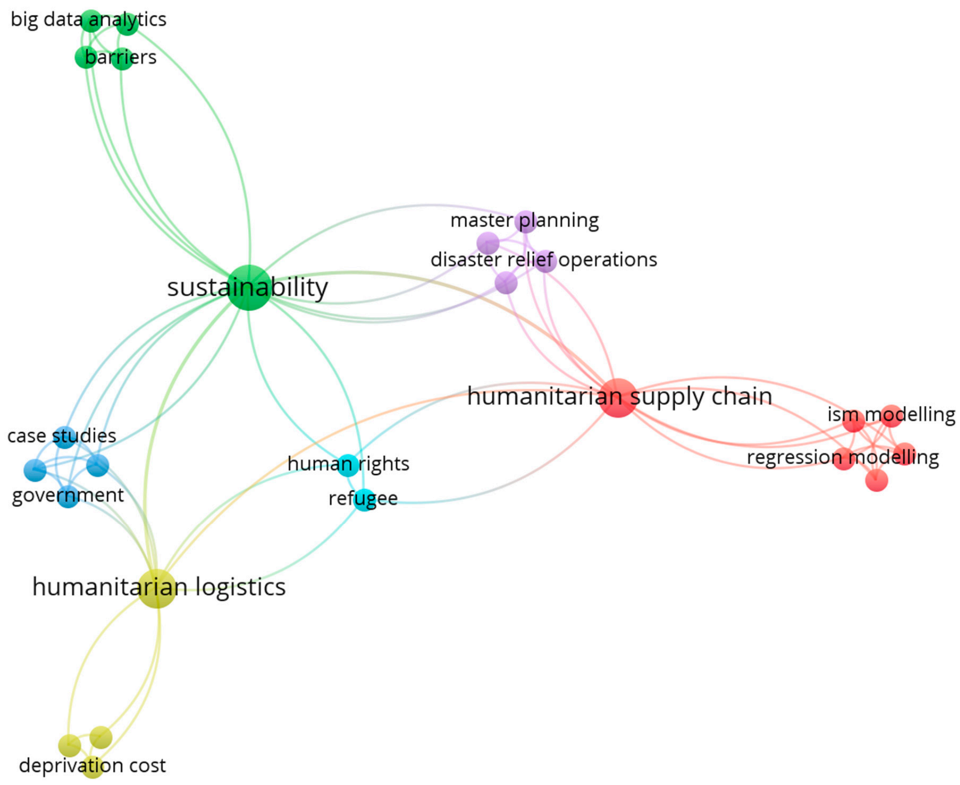


Figure 13. Sustainable Humanitarian Supply Chain via VOSviewer.

The connection between "sustainability" and "HSC" strongly emphasizes integrating sustainable logistics into HSCs. "Sustainability" is further linked to "Big Data Analytics" and "barriers", indicating the significant impact of Industry 4.0 technologies, specifically BDA, on sustainability within HSC. This connection highlights the importance of leveraging data analytics for managing SHSCs.

Between "humanitarian logistics" and "HSC", there are links to "human rights" and "refugees", implying that the humanitarian aspects of supply chains are closely associated with considerations related to fundamental rights and migrant or evacuee populations. Moreover, the connection between "sustainability" and "HSC" extends to "master planning" and "disaster relief operations", emphasizing the importance of comprehensive planning and efficient response operations within sustainable HSCs. Figure 13, thus, suggests the critical role of sustainability, technology, humanitarian logistics, and their impact on human rights and disaster relief. This takes us to the keyword cloud for SHSCs, as displayed in Figure 14.

Figure 14. NVivo's word cloud of SHSCs: text-mined keywords for 2003–2022.

3.4. *Topical Trends by Year*

The focus in 2016 was on defining the structure of and emphasizing the importance of agility, adaptability, and alignment in HSCs. This contributed to the understanding of the unique characteristics of HSCs, which are distinct from commercial SCs [40].

The year 2017 marked the exploration of a comprehensive framework for designing and managing SHSCs. This research highlighted the need for supply chain design to align with relief organizations' enablers and the population's long-term requirements, socio-economic factors, and government contingencies to achieve sustainable performance [62].

Articles in 2019 underlined the importance of organizational coordination in SHSCs, particularly the challenges and mechanisms related to coordination between the private sector and humanitarian organizations. This year also saw the development of a multicriteria Master Planning Decision Support System to support tactical planning for SHSCs.

This system included sustainability metrics and aimed to enhance the performance of HSCs [33,63].

In 2020, lean readiness assessment models were developed to judge the preparedness of humanitarian organizations to adopt lean management practices. The models aimed to improve humanitarian organizations' efficiency and sustainability (economic and social aspects) under resource constraints [65].

The year 2021 saw a multidimensional approach to SHSCs, treating various aspects. The research identified and evaluated key challenges in SHSCs, particularly in response to the COVID-19 pandemic, and proposed strategies for overcoming these challenges. A multi-method simulation (MMS) approach was also developed to evaluate evacuation plans and consider sustainability factors. A fuzzy bi-level optimization model was introduced to confront supply shortages and inequitable distribution during large-scale natural disasters [36,64,66].

In 2022, publications expanded into the human rights and environmental aspects of SHSCs. The focus was on how sustainability in HSCs contributed to human rights protection in refugee settlements. Additionally, authors that year addressed BDA in SHSCs, exploring barriers and interactions associated with utilizing data analytics for managing HSCs [5,42,47,67].

These trends demonstrate a growing interest in developing sustainable, efficient, equitable, and accessible HSCs (see [75–77]). Researchers are exploring various dimensions and the environmental and social impacts of SHSCs. Moreover, the responses to worldwide issues such as climate change and the COVID-19 pandemic drive innovation in this field, as evidenced by the lean readiness assessment model and the consideration of BDA. This multidisciplinary approach reflects the dynamic nature of HSC research and the need for continuous improvement to address complex global challenges.

4. I4.0 for SHSCs in Climate-Changed World: Examples, Barriers, and Trends

The leading I4.0 technologies for SHSCs are: (1) AI-driven demand forecasting and real-time data analytics to improve decision making. BDA enhances visibility and coordination within HSCs, leading to sustainability. (2) BkCn facilitates improved collaboration in disaster relief operations. We highlight the following examples of I4.0 technologies utilized in SHSC based on the extant literature:

Automated robotics: In the context of nuclear radiation exposure, robotics played a crucial role in emergency responses during the 2011 Fukushima Daiichi earthquake and tsunami. However, the challenging environment, severe radiation, and the initial uncertainty about the effectiveness of robots posed significant hurdles. Bridging this gap required educating users in simulated environments using actual robots, emphasizing the importance of user training [25,78];

3DP: Additive manufacturing, called 3D printing, has revolutionized product design and production. Within the humanitarian sector, 3DP offers the potential to align supply with increasing global humanitarian demands [79]. It enables the cost-effective on-site construction of drugs, streamlining HSCs [80]. Another innovation aims to provide immediate on-site construction in disaster-affected areas. By using local materials and 3DP, minimal logistics are required [81]. However, research in this field is still nascent;

IoT: IoT is a network of physical objects that are digitally connected to sense, monitor, and interact within and between SC members. IoT impacts the everyday life and behavior of potential users. IoT heralds a vision of the future wherein connecting through a network of physical things, from cellphones to bank cards to refrigerators to smart bicycles, will enable immediate access to information about the physical world with its objects to maximize SC performance [52]. Therefore, IoT is vital in monitoring and tracking humanitarian aid, ensuring efficient distribution [82] within a sustainable supply chain perspective [83];

AI and ML: Integrating real-time data analytics and AI-powered demand forecasting enhances decision making and facilitates efficient resource allocation in humanitarian operations. AI-based decision support tools include One Concern, TweetTracker, CrisisMappers, INFORM, Adashi FirstResponse MDT, and Tractable [20,47]. Machine learning applications have analyzed the effectiveness of tsunami evacuation principles during natural disasters to mitigate fatality rates [84]. Many researchers acknowledge the limitations of using historical data, which may lead to missing or biased results, especially when dealing with unprecedented changes (i.e., COVID-19);

BkCn: BkCn has emerged as a powerful tool for transparency, traceability, and accountability in aid distribution within supply chains. It enhances trust and responsibility in humanitarian operations, driving sustainability in global supply chains [85,86]. The promise of BkCn technology as a sustainability-oriented innovation is increasingly recognized [87,88];

Drones: Drones are currently utilized in humanitarian efforts primarily for disaster mapping and medical supply delivery [53,89].

Within the context of SHSCs, the successful integration of I4.0 technologies in response to disasters and a global pandemic is provided in Table 5. These illustrative examples highlight outcomes derived from an extensive literature review. As mentioned previously, the role of HSCs in the environment of COVID-19 differs significantly from their role in more typical disasters such as earthquakes, droughts, or floods. Because the COVID-19 pandemic profoundly affected health, economic, social, and industrial domains, supply chain management was severely disrupted, hindering the movement of essential supplies. Therefore, I4.0 technologies were urgently needed to adapt to a dynamic situation. Ivanov and Dolgui [18] suggested that these technologies had the potential to mitigate supply chain risks resulting from disruptions such as the pandemic. In this regard, various efforts and considerations advocating for I4.0 technology application to overcome those challenges [90] have accelerated in recent years [91].

Table 5. Applications of I4.0 technologies in HSCs.

I4.0 Technologies	Risk Assessment	Disaster Preparedness	Response Management	Recovery and Relief
Automated Robotics	Early risk identification		Rescue	Aid distribution
3DP			Rapid manufacturing (relief items and medical devices)	On-site construction (shelters, buildings)
IoT			Real-time monitoring	Tracking (sensor technologies) for relief
Drones	Early risk identification		Gathering data	Distribution
BkCn			Donor/anti-fraud	Secure transaction
AI and ML	Early risk identification/ Early warning systems	Predictive analytics/ Evacuation principles	Demand forecasting/ optimizing decisions	
Augmented Reality (AR) and Virtual Reality (VR)	Simulating disaster scenarios	Education	Training volunteers	Remote guidance for field operations

More successful case studies and applications will emerge as these I4.0 technologies mature and gain wider acceptance. So far, I4.0 applications have been primarily focused on commercial supply chains, and with this paper, we assert the need for I4.0 frameworks to be engaged in HSCs. For instance, a case study related to the supplier selection process for acquiring medical devices [92] could be studied in the context of HSCs. Non-governmental organizations such as the Red Cross or Médecins Sans Frontières (Doctors Without Borders) [93] can benefit from BDA to predict disease outbreaks and plan their medical SCs. Accordingly, in disaster relief operations, IoT technologies, such as sensors on relief shipments, can provide real-time data on the location, temperature, and condition of medical supplies to ensure that the right resources reach the affected areas on time. At the same time, BkCn can be used to improve the tracking and traceability of cash transfers and humanitarian aid. Moreover, such aid organizations can utilize AI algorithms to analyze historical data, weather patterns, and population movements to improve demand forecasting for essential goods during humanitarian crises and employ digital fabrication via 3DP [79], possibly to shorten supply times for emergency tools.

However, adopting I4.0 technologies in SHSCs is accompanied by several challenges and barriers stemming from the unique nature of the humanitarian sector and its operational context. Some key considerations follow:

- Resource/financial constraints: Humanitarian organizations often operate on tight budgets, with limited funds allocated for technology adoption. The initial investment required for I4.0 technologies, such as advanced data analytics or IoT devices, may be prohibitive;
- Lack of infrastructure and connectivity: Many humanitarian operations occur in remote or disaster-stricken areas where basic infrastructure is lacking. The absence of reliable power sources, internet connectivity, and communication networks can impede the deployment of I4.0 solutions;
- Data security and privacy concerns: Humanitarian organizations deal with highly sensitive data, including personal and crisis-related details. Implementing I4.0 technologies may raise data security and privacy concerns, requiring robust safeguards to protect against unauthorized access or misuse;
- Humanitarian principles and ethical dilemmas: Adopting technologies like AI and automated decision making may raise ethical concerns in the humanitarian sector. Balancing the potential benefits of I4.0 with adherence to humanitarian principles, such as neutrality and impartiality, can be challenging;
- Capacity building: Humanitarian workers may lack the skills to effectively use and manage I4.0 technologies. Building the capacity of personnel through training programs becomes crucial in ensuring successful implementation;
- Integration challenges: Existing systems in HSCs may not be compatible with newer I4.0 technologies. Ensuring seamless integration and interoperability between platforms and technologies is a significant challenge;
- Community engagement: Humanitarian efforts require a people-centric approach. In adopting I4.0 technologies, it is essential to consider the cultural context and engage with local communities to avoid unintended negative consequences or resistance to technology;
- Compliance and regulations: Adhering to local and international regulations, particularly in conflict zones or areas with unstable governance, can pose challenges. Navigating legal frameworks and obtaining necessary approvals may be time-consuming;
- Maintenance and upkeep: I4.0 technologies require ongoing maintenance and updates. Ensuring the long-term sustainability of these solutions, especially in resource-constrained environments, can be a hurdle.

Overcoming these challenges requires a thoughtful and adaptive approach involving collaboration between humanitarian organizations, technology providers, governments, and local communities to ensure that the benefits of I4.0 technologies are realized without compromising humanitarian principles or exacerbating existing vulnerabilities.

As evidenced so far, gauging I4.0 technologies in SHSCs is a dynamic area with ongoing developments. Future trends are expected to drive resilience, sustainability, and efficiency improvements. Next, we identify the following emerging technologies and innovative approaches that could shape the future of integrating I4.0 technologies into SHSCs:

➢ High-speed connectivity: The widespread adoption of 5G technology will enable faster and more reliable communication. This is crucial for real-time monitoring, data exchange, and coordination within SHSCs, especially in remote or disaster-affected areas;

- ➢ Decentralized (localized) decision making: Edge computing brings computational capabilities closer to the data source, reducing latency. In SHSCs, this can enable real-time decision making at the point of need, enhancing responsiveness and reducing dependence on centralized data processing;
- ➢ Digital twins for SC simulation: Digital twin technology creates virtual replicas of physical SC assets, allowing for simulations and predictive modeling. This can help optimize SC operations, identify vulnerabilities, and test many scenarios for better resilience;
- ➢ SC robotics collaboration: Future trends involve more advanced collaboration between human workers and robots in SC operations, including autonomous robots working alongside human personnel in warehouses and using AI to adapt to changing conditions;
- ➢ Smart packaging with IoT sensors: Smart packaging equipped with IoT sensors can monitor the condition of goods in real time, ensuring perishable items are transported under optimal conditions, reducing waste, and maintaining the quality of delivered aids;
- ➢ Circular SCs: Future SHSCs are likely to embrace circular SC principles, focusing on reducing waste and promoting the reuse and recycling of materials. This holistic approach contributes to environmental sustainability and aligns with broader global goals, including SDGs [94,95];
- ➢ Green energy: Integrating renewable energy sources like solar and wind into supply chain operations supports sustainability goals. This can involve using renewable energy to power warehouses, distribution centers, and vehicles used in SHSCs;
- ➢ Interconnected ecosystems: Collaborative platforms and digital ecosystems facilitate stakeholder communication and coordination. Interconnectedness improves overall SC visibility, allowing for better collaboration between humanitarian organizations, governments, and other partners.

Embracing these future trends may contribute to building more resilient, sustainable, and responsive SHSCs. However, it is essential to consider the ethical implications, data privacy, and community engagement aspects to ensure that adopting these technologies aligns with humanitarian principles and goals.

In a climate-changed world with fast-paced technological advances, sustainable development (i.e., meeting the needs of today without compromising those of future generations) should be the guidepost for fostering business, society, cultural diversity, viability, and the environment. Nevertheless, political turmoil, social divides, rising nationalism, ongoing wars (e.g., Russia–Ukraine, Israel–Palestine), and a fragile global economy further strain global SCs, making SHSCs even more vulnerable. To that end, managing SHSCs in the context of sustainable development is not immune from political economy [96,97], calls for comprehensive prescriptive models, e.g., [98], that account for uncertainties inherent in humanitarian operations, and requires frequently taking stock of advances in technology along with scholarly research [99,100].

5. Concluding Remarks

In the face of turbulent economic and political conditions and, most notably, the climate crisis, designing and implementing resilient and sustainable supply chains is essential for environmental, economic, social, and cultural viability. This paper defines a Sustainable Humanitarian Supply Chain (SHSC) and calls for further awareness and action to improve SHSCs benefiting from advances in science and computing. Intelligent I4.0 technologies such as BkCn, IoT, BDA, AI, and robotics offer continuous improvement in forecasting demand and optimizing the allocation and delivery of aid resources in responding to humanitarian crises in a climate-changed world.

Disasters do not differentiate between borders. It is increasingly evident that a global, collective effort by all nations is a must in cooperating in every stage of humanitarian aid operations, from preparedness to rescue to relief. Mitigating the ramifications of natural and human-made disasters warrants deliberate and concerted efforts by governments, communities, civil organizations, and non-profit and for-profit organizations. I4.0 technologies offer numerous opportunities to better collect data, coordinate, and respond to those in need while addressing the quadruple bottom-line approach to sustainability, enabling SHSCs.

HSCs have many strengths that commercial supply chains could use to improve their performance and competitive advantage. For example, as we have seen, they are very agile, adaptable, and capable of setting up and changing supply chains quickly and under challenging conditions. They can align the differing needs and dynamic roles of many players. Companies increasingly need similar skills given the dynamic demands and risks of operating global supply chains and the increased central role of logistics in making profits under these conditions. Businesses could learn more about vulnerability assessment, preparation, and response to disasters (natural or human-made, accidental or deliberate, such as terrorist attacks). Conversely, commercial supply chains have educated talents, assets, and infrastructure that could share resources with SHSCs, for instance, in mass evacuations.

Disasters caused by climate change tend to be more sudden and difficult to predict. Climate-related disasters such as heavy rains, hurricanes, droughts, and heat waves require rapid response. Therefore, with the variety and increasing frequency of disasters, SHSCs may be tailored at the community level. A curious topic of research would be optimal local and robust SHSC design based on a specific region and its unique disaster risk profile.

Other promising research venues include stakeholder analysis for SHSCs, feasibility studies for I4.0 technologies to be deployed for preparedness and mitigation, integrating equity and accessibility features in humanitarian I4.0 technologies, the further impact of Industry 5.0 (I4.0 with human cognition embedded in it), and last but not least, creating awareness and connectedness between civilians to cooperate and help during the increasingly probing turbulent environments in a climate-changed world.

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Abbreviation

AI	Artificial intelligence
BDA	Big data analytics
BkCn	Blockchain
HSC	Humanitarian supply chain
IoT	Internet of Things
I4.0	Industry 4.0
ML	Machine learning
QBL	Quadruple bottom line
SC	Supply chain
SDG	United Nations Sustainable Development Goal
SHSC	Sustainable HSC
SSC	Sustainable SC
3DP	Three-dimensional printing

References

1. WFP. The United Nations World Food Programme (WFP), Blockchain Against Hunger: Harnessing Technology In Support of Syrian Refugees. 2017. Available online: https://www.wfp.org/news/blockchain-against-hunger-harnessing-technology-support-syrian-refugees (accessed on 11 September 2023).
2. Govindan, K.; Kannan, D.; Jørgensen, T.B.; Nielsen, T.S. Supply Chain 4.0 performance measurement: A systematic literature review, framework development, and empirical evidence. *Transp. Res. Part E Logist. Transp. Rev.* **2022**, *164*, 102725. [CrossRef]
3. Papadopoulos, T.; Gunasekaran, A.; Dubey, R.; Altay, N.; Childe, S.J.; Fosso-Wamba, S. The role of Big Data in explaining disaster resilience in supply chains for sustainability. *J. Clean. Prod.* **2017**, *142*, 1108–1118. [CrossRef]
4. Wamba, S.F. Humanitarian supply chain: A bibliometric analysis and future research directions. *Ann. Oper. Res.* **2020**, *319*, 937–963. [CrossRef]
5. Bag, S.; Gupta, S.; Wood, L. Big data analytics in sustainable humanitarian supply chain: Barriers and their interactions. *Ann. Oper. Res.* **2022**, *319*, 721–760. [CrossRef]
6. Dubey, R.; Luo, Z.; Gunasekaran, A.; Akter, S.; Hazen, B.T.; Douglas, M.A. Big data and predictive analytics in humanitarian supply chains: Enabling visibility and coordination in the presence of swift trust. *Int. J. Logist. Manag.* **2018**, *29*, 485–512. [CrossRef]
7. Thomas, A.S.; Kopczak, L.R. From logistics to supply chain management: The path forward in the humanitarian sector. *Fritz Inst.* **2005**, *15*, 1–15.
8. Van Wassenhove, L.N. Humanitarian aid logistics: Supply chain management in high gear. *J. Oper. Res. Soc.* **2006**, *57*, 475–489. [CrossRef]
9. Elkazini, R.; Hadini, M.; Ali, M.B.; Sahaf, K.; Rifai, S. Impacts of adopting Industry 4.0 technologies on supply chain management: A literature review. *Int. J. Innov. Appl. Stud.* **2021**, *31*, 829–835.
10. Van Wassenhove, L.N.; Pedraza Martinez, A.J. Using OR to adapt supply chain management best practices to humanitarian logistics. *Int. Trans. Oper. Res.* **2012**, *19*, 307–322. [CrossRef]
11. Tomasini, R.M.; Van Wassenhove, L.N. From preparedness to partnerships: Case study research on humanitarian logistics. *Int. Trans. Oper. Res.* **2009**, *16*, 549–559. [CrossRef]
12. IDMC 2023 Global Report on Internal Displacement, Internal Displacement Monitoring Centre (IDMC). 2023. Available online: https://www.internal-displacement.org/global-report/grid2023 (accessed on 2 January 2024).
13. Yun, N.Y.; Ülkü, M.A. Sustainable Supply Chain Risk Management in a Climate-Changed World: Review of Extant Literature, Trend Analysis, and Guiding Framework for Future Research. *Sustainability* **2023**, *15*, 13199. [CrossRef]
14. Oloruntoba, R.; Gray, R. Humanitarian aid: An agile supply chain? *Supply Chain. Manag. Int. J.* **2006**, *11*, 115–120. [CrossRef]
15. Kovács, G.; Spens, K.M. Humanitarian logistics in disaster relief operations. *Int. J. Phys. Distrib. Logist. Manag.* **2007**, *37*, 99–114. [CrossRef]
16. Klumpp, M.; De Leeuw, S.; Regattieri, A.; De Souza, R. (Eds.) *Humanitarian Logistics and Sustainability*; Springer International Publishing: Berlin/Heidelberg, Germany, 2015.
17. Sharma, M.; Luthra, S.; Joshi, S.; Kumar, A. Developing a framework for enhancing survivability of sustainable supply chains during and post-COVID-19 pandemic. *Int. J. Logist. Res. Appl.* **2020**, *25*, 433–453. [CrossRef]
18. Ivanov, D.; Dolgui, A. A digital supply chain twin for managing the disruption risks and resilience in the era of Industry 4.0. *Prod. Plan. Control* **2021**, *32*, 775–788. [CrossRef]
19. Behl, A.; Dutta, P. Humanitarian supply chain management: A thematic literature review and future directions of research. *Ann. Oper. Res.* **2019**, *283*, 1001–1044. [CrossRef]
20. Shayganmehr, M.; Gupta, S.; Laguir, I.; Stekelorum, R.; Kumar, A. Assessing the role of industry 4.0 for enhancing swift trust and coordination in humanitarian supply chain. *Ann. Oper. Res.* **2021**. [CrossRef]
21. Shrivastav, S.K.; Bag, S. Humanitarian supply chain management in the digital age: A hybrid review using published literature and social media data. *Benchmarking Int. J.* **2023**, *ahead-of-print*. [CrossRef]
22. Gupta, S.; Altay, N.; Luo, Z. Big data in humanitarian supply chain management: A review and further research directions. *Ann. Oper. Res.* **2019**, *283*, 1153–1173. [CrossRef]
23. Dubey, R.; Bryde, D.J.; Dwivedi, Y.K.; Graham, G.; Foropon, C. Impact of artificial intelligence-driven big data analytics culture on agility and resilience in humanitarian supply chain: A practice-based view. *Int. J. Prod. Econ.* **2022**, *250*, 108618. [CrossRef]
24. Nabipour, M.; Ülkü, M.A. On deploying blockchain technologies in supply chain strategies and the COVID-19 pandemic: A systematic literature review and research outlook. *Sustainability* **2021**, *13*, 10566. [CrossRef]
25. Nagatani, K.; Kiribayashi, S.; Okada, Y.; Otake, K.; Yoshida, K.; Tadokoro, S.; Nishimura, T.; Yoshida, T.; Koyanagi, E.; Fukushima, M.; et al. Emergency response to the nuclear accident at the Fukushima Daiichi Nuclear Power Plants using mobile rescue robots. *J. Field Robot.* **2013**, *30*, 44–63. [CrossRef]
26. Ülkü, M.A.; Bell, K.M.; Wilson, S.G. Modeling the impact of donor behavior on humanitarian aid operations. *Ann. Oper. Res.* **2015**, *230*, 153–168. [CrossRef]
27. Mosanna, Z.; Heydari, J.; Torabi, S.A.; Ülkü, M.A. Donating to a good cause: Optimal coordination design of a dyadic supply chain with socially aware consumers. *Comput. Ind. Eng.* **2022**, *169*, 108243. [CrossRef]
28. Sahebi, I.G.; Masoomi, B.; Ghorbani, S. Expert oriented approach for analyzing the blockchain adoption barriers in humanitarian supply chain. *Technol. Soc.* **2020**, *63*, 101427. [CrossRef]

29. UNSDG Report. The Sustainable Development Goals Report. 2022. Available online: https://unstats.un.org/sdgs/report/2022/ (accessed on 7 July 2023).
30. Besiou, M.; Pedraza-Martinez, A.J.; Van Wassenhove, L.N. Humanitarian operations and the UN sustainable development goals. *Prod. Oper. Manag.* **2021**, *30*, 4343–4355. [CrossRef]
31. UNDRR. *United Nations Office for Disaster Risk Reduction*; Global Assessment Report on Disaster Risk Reduction; UNDRR: Geneva, Switzerland, 2019; Available online: https://gar.unisdr.org/sites/default/files/reports/2019-05/full_gar_report.pdf (accessed on 7 July 2023).
32. Starr, M.K.; Van Wassenhove, L.N. Introduction to the special issue on humanitarian operations and crisis management. *Prod. Oper. Manag.* **2014**, *23*, 925–937. [CrossRef]
33. Laguna-Salvadó, L.; Lauras, M.; Okongwu, U.; Comes, T. A multicriteria Master Planning DSS for a sustainable humanitarian supply chain. *Ann. Oper. Res.* **2019**, *283*, 1303–1343. [CrossRef]
34. Pournader, M.; Kach, A.; Talluri, S. A review of the existing and emerging topics in the supply chain risk management literature. *Decis. Sci.* **2020**, *51*, 867–919. [CrossRef] [PubMed]
35. Spieske, A.; Birkel, H. Improving supply chain resilience through industry 4.0: A systematic literature review under the impressions of the COVID-19 pandemic. *Comput. Ind. Eng.* **2021**, *158*, 107452. [CrossRef] [PubMed]
36. Karuppiah, K.; Sankaranarayanan, B.; Ali, S.M.; Paul, S.K. Key challenges to sustainable humanitarian supply chains: Lessons from the COVID-19 pandemic. *Sustainability* **2021**, *13*, 5850. [CrossRef]
37. Ivanov, D.; Tang, C.S.; Dolgui, A.; Battini, D.; Das, A. Researchers' perspectives on Industry 4.0: Multidisciplinary analysis and opportunities for operations management. *Int. J. Prod. Res.* **2021**, *59*, 2055–2078. [CrossRef]
38. Dubey, R.; Gunasekaran, A.; Bryde, D.J.; Dwivedi, Y.K.; Papadopoulos, T. Blockchain technology for enhancing swift-trust, collaboration and resilience within a humanitarian supply chain setting. *Int. J. Prod. Res.* **2020**, *58*, 3381–3398. [CrossRef]
39. Gatignon, A.; Van Wassenhove, L.N.; Charles, A. The Yogyakarta earthquake: Humanitarian relief through IFRC's decentralized supply chain. *Int. J. Prod. Econ.* **2010**, *126*, 102–110. [CrossRef]
40. Dubey, R.; Gunasekaran, A. The sustainable humanitarian supply chain design: Agility, adaptability and alignment. *Int. J. Logist. Res. Appl.* **2016**, *19*, 62–82. [CrossRef]
41. Bhattacharya, S.; Hasija, S.; Van Wassenhove, L.N. Designing efficient infrastructural investment and asset transfer mechanisms in humanitarian supply chains. *Prod. Oper. Manag.* **2014**, *23*, 1511–1521. [CrossRef]
42. Karl, A.A.; Scholz Karl, J. Human rights for refugees: Enhancing sustainable humanitarian supply chain to guarantee a health environment in refugee settlements. *J. Humanit. Logist. Supply Chain. Manag.* **2022**, *12*, 382–403. [CrossRef]
43. Halldórsson, Á.; Kovács, G. The Sustainable Agenda and Energy Efficiency: Logistics Solutions and Supply Chains in Times of Climate Change. *Int. J. Phys. Distrib. Logist. Manag.* **2010**, *40*, 5–13. [CrossRef]
44. Shackleton, S.E.; Shackleton, C.M. Linking Poverty, HIV/AIDS and Climate Change to Human and Ecosystem Vulnerability in Southern Africa: Consequences for Livelihoods and Sustainable Ecosystem Management. *Int. J. Sustain. Dev. World Ecol.* **2012**, *19*, 275–286. [CrossRef]
45. Lee, H.L. The Triple-A Supply Chain. *Harv. Bus. Rev.* **2004**, *82*, 102–112.
46. Ülkü, M.A.; Engau, A. Sustainable supply chain analytics. In Industry, Innovation and Infrastructure. In *Encyclopedia of the UN Sustainable Development Goals*; Leal Filho, W., Azul, A.M., Brandli, L., Lange Salvia, A., Wall, T., Eds.; Springer: Cham, Switzerland, 2021; pp. 1123–1134.
47. Oguntola, I.O.; Ülkü, M.A. Artificial Intelligence for Sustainable Humanitarian Logistics. In *Encyclopedia of Data Science and Machine Learning*; IGI Global: Hershey, PA, USA, 2023; pp. 2970–2983.
48. Hult, G.T.M.; Ketchen, D.J., Jr.; Slater, S.F. Information processing, knowledge development, and strategic supply chain performance. *Acad. Manag. J.* **2004**, *47*, 241–253. [CrossRef]
49. Ebinger, F.; Omondi, B. Leveraging digital approaches for transparency in sustainable supply chains: A conceptual paper. *Sustainability* **2020**, *12*, 6129. [CrossRef]
50. Rahimi, I.; Gandomi, A.H.; Fong, S.J.; Ülkü, M.A. *Big Data Analytics in Supply Chain Management: Theory and Applications*; CRC Press- T& F Group: Boca Raton, FL, USA, 2021.
51. Chalmeta, R.; Santos-deLeón, N.J. Sustainable supply chain in the era of industry 4.0 and big data: A systematic analysis of literature and research. *Sustainability* **2020**, *12*, 4108. [CrossRef]
52. Ülkü, M.A.; Mansouri, B. Supply Chain Analytics: Overview, Emerging Issues, and Research Outlook. In *The Palgrave Handbook of Supply Chain Management*; Springer: Berlin/Heidelberg, Germany, 2023. [CrossRef]
53. Kunovjanek, M.; Wankmüller, C. Containing the COVID-19 pandemic with drones-Feasibility of a drone enabled back-up transport system. *Transp. Policy* **2021**, *106*, 141–152. [CrossRef]
54. Hossain, M.K.; Thakur, V. Benchmarking healthcare supply chain by implementing Industry 4.0: A fuzzy-AHP-DEMATEL approach. *Benchmarking Int. J.* **2021**, *28*, 556–581. [CrossRef]
55. Ali, I.; Kannan, D. Mapping research on healthcare operations and supply chain management: A topic modelling-based literature review. *Ann. Oper. Res.* **2022**, *315*, 29–55. [CrossRef] [PubMed]
56. Khan, M.K.; Trinh, H.H.; Khan, I.U.; Ullah, S. Sustainable economic activities, climate change, and carbon risk: An international evidence. *Environ. Dev. Sustain.* **2022**, *24*, 9642–9664. [CrossRef] [PubMed]

57. Kumar, P.; Singh, R.K. Application of Industry 4.0 technologies for effective coordination in humanitarian supply chains: A strategic approach. *Ann. Oper. Res.* **2022**, *319*, 379–411. [CrossRef]
58. Frederico, G.F.; Kumar, V.; Garza-Reyes, J.A.; Kumar, A.; Agrawal, R. Impact of I4. 0 technologies and their interoperability on performance: Future pathways for supply chain resilience post-COVID-19. *Int. J. Logist. Manag.* **2023**, *34*, 1020–1049. [CrossRef]
59. Colicchia, C.; Strozzi, F. Supply chain risk management: A new methodology for a systematic literature review. *Supply Chain Manag. Int. J.* **2012**, *17*, 403–418. [CrossRef]
60. Colicchia, C.; Creazza, A.; Noè, C.; Strozzi, F. Information sharing in SCs: A review of risks and opportunities using the systematic literature network analysis (SLNA). *Supply Chain Manag. Int. J.* **2019**, *24*, 5–21. [CrossRef]
61. Harzing, A.W.; Alakangas, S. Google Scholar, Scopus and the Web of Science: A longitudinal and cross-disciplinary comparison. *Scientometrics* **2016**, *106*, 787–804. [CrossRef]
62. Kunz, N.; Gold, S. Sustainable humanitarian supply chain management–exploring new theory. *Int. J. Logist. Res. Appl.* **2017**, *20*, 85–104. [CrossRef]
63. Li, C.; Zhang, F.; Cao, C.; Liu, Y.; Qu, T. Organizational coordination in sustainable humanitarian supply chain: An evolutionary game approach. *J. Clean. Prod.* **2019**, *219*, 291–303. [CrossRef]
64. Cao, C.; Liu, Y.; Tang, O.; Gao, X. A fuzzy bi-level optimization model for multi-period post-disaster relief distribution in sustainable humanitarian supply chains. *Int. J. Prod. Econ.* **2021**, *235*, 108081. [CrossRef]
65. Shafiq, M.; Soratana, K. Lean readiness assessment model–a tool for Humanitarian Organizations' social and economic sustainability. *J. Humanit. Logist. Supply Chain. Manag.* **2020**, *10*, 77–99. [CrossRef]
66. Sopha, B.M.; Triasari, A.I.; Cheah, L. Sustainable humanitarian operations: Multi-method simulation for large-scale evacuation. *Sustainability* **2021**, *13*, 7488. [CrossRef]
67. Jamali, A.; Ranjbar, A.; Heydari, J.; Nayeri, S. A multi-objective stochastic programming model to configure a sustainable humanitarian logistics considering deprivation cost and patient severity. *Ann. Oper. Res.* **2022**, *319*, 1265–1300. [CrossRef]
68. Ruesch, L.; Tarakci, M.; Besiou, M.; Van Quaquebeke, N. Orchestrating coordination among humanitarian organizations. *Prod. Oper. Manag.* **2022**, *31*, 1977–1996. [CrossRef]
69. Akter, S.; Wamba, S.F. Big data and disaster management: A systematic review and agenda for future research. *Ann. Oper. Res.* **2019**, *283*, 939–959. [CrossRef]
70. Upadhyay, A.; Mukhuty, S.; Kumari, S.; Garza-Reyes, J.A.; Shukla, V. A review of lean and agile management in humanitarian supply chains: Analysing the pre-disaster and post-disaster phases and future directions. *Prod. Plan. Control* **2022**, *33*, 641–654. [CrossRef]
71. Saldanha-da-Gama, F. Facility location in logistics and transportation: An enduring relationship. *Transp. Res. Part E Logist. Transp. Rev.* **2022**, *166*, 102903. [CrossRef]
72. Akbari, V.; Shiri, D.; Salman, F.S. An online optimization approach to post-disaster road restoration. *Transp. Res. Part B Methodol.* **2021**, *150*, 1–25. [CrossRef]
73. Castleberry, A. *NVivo 10, Version 10*; QSR International: Burlington, MA, USA, 2012.
74. Dhakal, K. NVivo. *J. Med. Libr. Assoc.* **2022**, *110*, 270. [CrossRef]
75. Rojas Trejos, C.A.; Meisel, J.D.; Adarme Jaimes, W. Humanitarian aid distribution logistics with accessibility constraints: A systematic literature review. *J. Humanit. Logist. Supply Chain Manag.* **2023**, *13*, 26–41. [CrossRef]
76. Sengul Orgut, I.; Brock, L.G., III; Davis, L.B.; Ivy, J.S.; Jiang, S.; Morgan, S.D.; Uzsoy, R.; Hale, C.; Middleton, E. Achieving equity, effectiveness, and efficiency in food bank operations: Strategies for feeding America with implications for global hunger relief. In *Advances in Managing Humanitarian Operations*; Springer: Berlin/Heidelberg, Germany, 2016; pp. 229–256.
77. Sengul Orgut, I.; Lodree, E.J. Equitable distribution of perishable items in a food bank supply chain. *Prod. Oper. Manag.* **2023**, *32*, 002–3021. [CrossRef]
78. Nagatani, K.; Kiribayashi, S.; Okada, Y.; Tadokoro, S.; Nishimura, T.; Yoshida, T.; Koyanagi, E.; Hada, Y. November. Redesign of rescue mobile robot Quince. In Proceedings of the 2011 IEEE International Symposium on Safety, Security, and Rescue robotics, Kyoto, Japan, 1–5 November 2011; IEEE: Piscataway, NJ, USA, 2011; pp. 13–18.
79. Corsini, L.; Aranda-Jan, C.B.; Moultrie, J. The impact of 3D printing on the humanitarian supply chain. *Prod. Plan. Control* **2022**, *33*, 692–704. [CrossRef]
80. Papadimitriou, P.; Andriotis, E.G.; Fatouros, D.; Tzetzis, D. Design and Prototype Fabrication of a Cost-Effective Microneedle Drug Delivery Apparatus Using Fused Filament Fabrication, Liquid Crystal Display and Semi-Solid Extrusion 3D Printing Technologies. *Micromachines* **2022**, *13*, 1319. [CrossRef] [PubMed]
81. Koç, M.; Khan, S.A.; Ilcan, H.; Sahmaran, M. Conceptual design of autonomous rapid printing system for emergency and humanitarian needs. *Mater. Today Proc.* **2022**, *70*, 1–5. [CrossRef]
82. Aranda, D.A.; Fernández, L.M.M.; Stantchev, V. Integration of Internet of Things (IoT) and blockchain to increase humanitarian aid supply chains performance. In Proceedings of the 2019 5th International Conference on Transportation Information and Safety (ICTIS), Liverpool, UK, 14–17 July 2019; IEEE: Piscataway, NJ, USA, 2019; pp. 140–145.
83. Manavalan, E.; Jayakrishna, K. A review of Internet of Things (IoT) embedded sustainable supply chain for industry 4.0 requirements. *Comput. Ind. Eng.* **2019**, *127*, 925–953. [CrossRef]
84. Yun, N.Y.; Lee, S.W. Analysis of effectiveness of tsunami evacuation principles in the 2011 Great East Japan tsunami by using text mining. *Multimed. Tools Appl.* **2016**, *75*, 12955–12966. [CrossRef]

85. Marsal-Llacuna, M.L. The people's smart city dashboard (PSCD): Delivering on community-led governance with blockchain. *Technol. Forecast. Soc. Change* **2020**, *158*, 120150. [CrossRef]
86. Saberi, S.; Kouhizadeh, M.; Sarkis, J.; Shen, L. Blockchain technology and its relationships to sustainable supply chain management. *Int. J. Prod. Res.* **2019**, *57*, 2117–2135. [CrossRef]
87. Esmaeilian, B.; Sarkis, J.; Lewis, K.; Behdad, S. Blockchain for the future of sustainable supply chain management in Industry 4.0. *Resour. Conserv. Recycl.* **2020**, *163*, 105064. [CrossRef]
88. Mangla, S.K.; Kazançoğlu, Y.; Yıldızbaşı, A.; Öztürk, C.; Çalık, A. A conceptual framework for blockchain-based sustainable supply chain and evaluating implementation barriers: A case of the tea supply chain. *Bus. Strategy Environ.* **2022**, *31*, 3693–3716. [CrossRef]
89. Wang, N.; Christen, M.; Hunt, M.; Biller-Andorno, N. Supporting value sensitivity in the humanitarian use of drones through an ethics assessment framework. *Int. Rev. Red Cross* **2022**, *104*, 1397–1428. [CrossRef]
90. Tang, C.S.; Veelenturf, L.P. The strategic role of logistics in the industry 4.0 era. *Transp. Res. Part E Logist. Transp. Rev.* **2019**, *129*, 1–11. [CrossRef]
91. Naseem, M.H.; Yang, J. Role of industry 4.0 in supply chains sustainability: A systematic literature review. *Sustainability* **2021**, *13*, 9544. [CrossRef]
92. ForouzeshNejad, A.A. Leagile and sustainable supplier selection problem in the Industry 4.0 era: A case study of the medical devices using hybrid multi-criteria decision making tool. *Environ. Sci. Pollut. Res.* **2023**, *30*, 13418–13437. [CrossRef]
93. Michel, S.; Gerbaix, S.; Bidan, M. Dimensions and sub-dimensions of emergency supply chain resilience: A case study of Médecins Sans Frontières Logistique during the COVID-19 pandemic. *Supply Chain. Manag.* **2023**, *28*, 939–953. [CrossRef]
94. Schroeder, P.; Anggraeni, K.; Weber, U. The Relevance of Circular Economy Practices to the Sustainable Development Goals. *J. Ind. Ecol.* **2019**, *23*, 77–95. [CrossRef]
95. Ülkü, M.A.; Skinner, D.M.; Yıldırım, G. Toward Sustainability: A Review of Analytical Models for Circular Supply Chains. In *Circular Economy Supply Chains: From Chains to Systems*; Bals, L., Tate, W.L., Ellram, L.M., Eds.; Emerald Publishing Limited: Leeds, UK, 2022; pp. 215–236.
96. Tomislav, K. The concept of sustainable development: From its beginning to the contemporary issues. *Zagreb Int. Rev. Econ. Bus.* **2018**, *21*, 67–94.
97. Manioudis, M.; Meramveliotakis, G. Broad strokes towards a grand theory in the analysis of sustainable development: A return to the classical political economy. *New Political Econ.* **2022**, *27*, 866–878. [CrossRef]
98. Boostani, A.; Jolai, F.; Bozorgi-Amiri, A. Designing a sustainable humanitarian relief logistics model in pre-and postdisaster management. *Int. J. Sustain. Transp.* **2021**, *15*, 604–620.
99. Nawazish, M.; Nandakumar, M.K.; Mateen, A. Are humanitarian supply chains sustainable? A systematic review and future research themes. *Benchmarking Int. J.* 2023, *ahead-of-print*. [CrossRef]
100. Anjomshoae, A.; Banomyong, R.; Hossein Azadnia, A.; Kunz, N.; Blome, C. Sustainable humanitarian supply chains: A systematic literature review and research propositions. *Prod. Plan Control* **2023**. [CrossRef]