Original Paper

Bibliometric analysis of the transformation in air logistics operations in terms of digitalization and sustainability

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Abstract. *Digitalization and sustainability are essential in today's globalized business environment. Within the logistics sector, aviation plays a critical role in this dynamic environment by enabling rapid, safe transportation worldwide. While applying new approaches, air logistics processes should incorporate the technologies and applications enabled by digitalization, and*

consider environmental, social, and economic sustainability impacts. These can be mutually beneficial in that new digital technologies can reduce environmental impacts, make a social contribution, and increase economic gains. While there is rapidly expanding literature about integrating these concepts for various purposes in different sectors, applications in air logistics are particularly promising. Accordingly, this study contributes to digital and sustainable air logistics research by identifying current trends, revealing gaps in knowledge, and proposing future research directions. To do so, a literature review and a bibliometric analysis were conducted using VosViewer software. As a result, five potential research areas were proposed.

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1. Introduction

Two major trends shaping the current globalized business environment are digitalization and sustainability. With the Fourth Industrial Revolution, digitalization provides a significant competitive advantage for organizations. However, while focusing on economic gains, organizations also need to consider social and environmental issues. Therefore, sustainability and digitalization can be seen as two inseparable elements for organizations. As de Sousa Jabbour et al. (2018) put it, "these cannot individually be considered new industrial revolutions; through their overlap and synergy they may together comprise a distinct industrial wave that will change worldwide production systems forever" (p. 18).

The enormous changes introduced by digitalization and the search for sustainability affect supply chains at every stage. Being a core element, logistics operations need to meet the sustainability goals while staying up to date through digitalization. Within the current industrial revolution, logistics operations have evolved new characteristics, such as using big data analytics for route optimization, decreased storage requirements thanks to new techniques, optimized inventory control with autonomous robots, reduced bullwhip effects due to real-time information exchange, and minimal information disruption through smart items (Winkelhaus and Grosse, 2019).

With the increase in the level of digitalization in the logistics sector, the philosophy of doing business in warehouses is starting to change. With automated warehouses, new business models where heavy work is done by machines/robots and

people exist in the system with the role of supervisor will provide more efficient operations for many users (Bolatan, 2021). Digitization in warehouses is a very effective element that comes to the forefront in the transformation of logistics processes with the key factors of "Improve Accuracy, Increase Transparency, Boost Efficiency, Reduce Costs, and Strengthen Customer Service" (Marak, 2021). On the other hand, in parallel with the transformation experienced in the technological domain throughout the world, there are also various transformations in the social and economic sphere. In this sense, the benefits of the sharing economy to many different sectors and businesses will provide important opportunities for logistics and therefore storage. Warehouses located in almost every region of the world sometimes serve below their capacity and infrastructure facilities at various levels remain idle. With the cooperation of digitalization and sharing economy, stakeholders will be able to gain significant advantages in terms of sustainability with the shared warehouse philosophy, with the advantages of low cost, short delivery time, and easy cheap storage by using a warehouse near the region they want to export to through a digital platform (StoringCargo, 2021). This will undoubtedly create an important advantage for the stakeholders in the air cargo supply chain processes. Since airports are one of the logistics platforms/hubs like other warehouses and terminals, they can become a center of attraction for both their own processes and intermodal processes (El Ouadi et al., 2021).

This study focuses specifically on air logistics, a field which has been significantly impacted by the digital transformation because connectivity, mobility, and personalized services are prioritized. Indeed, recent technological developments and innovations have resulted in immense changes (Büyüközkan et al., 2019). Furthermore, digitalized air logistics, also known as Aviation 4.0, makes use of cyber-physical systems that support human decision making or even autonomous task completion (Kahraman and Aydın, 2021).

On the other hand, a critical issue for air logistics is applying sustainability principles to minimize negative environmental and social impacts while maintaining profitability. The air logistics industry has generally started to place more importance on sustainability in recent years. Mészáros et al. (2020), for example, offer the following suggestions to all stakeholders to increase sustainability and environmental awareness:

- designing sustainable operations
- observing sustainability criteria in new aircraft orders

- applying technological and environmental solutions for aircraft fuel, energy, and power systems
- digitalizing the documents and equipment used in passenger and cargo operations, such as paper and packaging

Each of these areas involves considerable investment in research and development. For example, as regards technological and environmental solutions, the use of abundant fossil fuels for air transportation has a significant impact detrimental to the environment (Johnson et al., 2018) and. From this perspective, hydrogen powered air transportation can be seen as a strong alternative to fossil fuels, and thereby an important step for sustainable aviation (Yussaf et al., 2022). Proponents of this perspective believe that zero emissions could be achieved in air transportation and would be beneficial for especially environmental sustainability by hydrogen powered systems (Khandelwal et al., 2013).

The present study focuses on the integration of digitalization and sustainability practices in air logistics. Although digitalization has a great potential to support sustainable processes, there is a gap in air logistics regarding the integration of digitalization and sustainability.

Accordingly, our aim is to identify current trends and future research directions for sustainable air logistics in the digital era by conducting a bibliometric analysis. To do so, we first analyse recent studies under different classifications. Secondly, we use Vosviewer to conduct a co-occurrence analysis to investigate future research directions in more detail.

The main contribution of this study is that it identifies ways to integrate digitalization and sustainability practices in air logistics, thereby expanding both theoretical and practical knowledge. Furthermore, the revealed gap in knowledge can encourage future researchers to focus on this field. This area also offers promising practical applications for air logistics to use digital approaches not only for economic gains but also to reduce harmful environmental impacts and increase social wellbeing.

This paper is structured as follows. First, a literature review is presented. Then the research methodology is explained. The fourth section presents the findings regarding current trends and the bibliometric analysis. The fifth section future discusses possible research directions based on the findings while the final section suggests some conclusions.

2. Literature review

Various academic studies have investigated digitalization and sustainability, although only a few have focused on air logistics specifically, mostly regarding technology-based transformations and applications. More research is needed, especially given the ever-increasing impact of digitalization on the logistics industry. While operations currently rely mainly on human brain power, the system will become too difficult to manage in this way as transportation services become more complex and modular, and consumer needs more variable and demanding (Bavrin et al., 2021). At this point, digital tools will become essential.

The importance of integrating digitalization elements into supply chain processes, especially for transportation and distribution stages is increasingly recognized. In China, for example, during the Covid-19 pandemic, businesses used smart/digital logistics technology to conduct important operations by estimating the availability of medical supplies (Li, 2020). Based on this experience, Li (2020) recommended the complete digital integration of air logistics operations. As an essential branch of logistics, humanitarian logistics operations are particularly significant examples here as it is critical to consider all micro and macro factors to ensure sustainability. Given recent experience, in the event of any future pandemic or other disaster, integrated digital tools will contribute significantly to the sustainability of operations by creating value and building trust in the supply chain (Baffoe and Luo, 2021). Air logistics operations, whose importance and popularity have increased with the pandemic, stand out as an example of the sustainability-digitalization relationship.

According to the International Civil Aviation Organization (ICAO), the main sustainability areas to prioritize in air transport are technology development, operational processes, and energy use. The ICAO highlights the importance of stakeholders in technological investments and argues that this situation may be affected by the current damage caused by the Covid-19 pandemic (Bartle et al., 2021). On the other hand, while the sector's future will be based on passenger-oriented operations, businesses should not ignore the opportunity for digitalization investments in air logistics operations in the pause due to the pandemic.

Regarding the sustainability of aviation operations, several large projects have been implemented, such as SESAR[1] in Europe and NextGen[2] in the USA, while the development of new technologies, standards, and procedures by all stakeholders is also very important (Guimarans et al., 2019). Indeed, many elements

[1] https://www.sesarju.eu/ (14.01.2022)
[2] https://www.faa.gov/nextgen/ (14.01.2022)

need to be transformed using digitalization to ensure sustainability, from airline passenger transportation to logistics processes, and from aircraft technology to airport operations. For example, Choi et al. (2019) identified various risks in air logistics supply chain operations and highlighted the application of blockchain. Similarly, di Vaio et al. (2020) showed that blockchain technology increased sustainability in airport operations. In another study of airports, Kelemen et al. (2020) proposed training content for an information system to improve sustainable risk assessment.

Ordieres-Mere et al. 2020) examined how the digital transformation in the manufacturing and aviation sectors can promote sustainability, particularly through knowledge creation and new strategies. Portapas et al. (2021) focused on Vertical Take-off and Landing (VTOL) aircraft as a symbolic example of digitalization and technological sustainability in aviation. Despite their limited use due to high cost and lack of supply, VTOL aircraft offer economic advantages by saving time and money, flexible planning possibilities, and environmental sensitivity.

As in the air transport sector generally, sustainability in air logistics operations depends crucially on fuel consumption or transforming energy resources. Thus, matching the basic structure of aircraft and energy consumption with the concept of digital twins is one of the key strategies for sustainability (Portapas et al., 2021). This aircraft technology will enable the expansion of the "green logistics" approach, currently one of the prominent business models for sustainability in the logistics industry (Barykin et al., 2021). According to Wu and Yang (2021), the main success factors for environmental sustainability in air logistics are aircraft weight, energy conversation, and fuel efficiency. One of the key drivers of this transformation will be technology and digitalization, especially of aircraft and their components.

According to a 2021 report from the International Air Cargo Association (TIACA), trust, safety, and digitalization are important in sustainable air cargo while the industry's vision should commit to and develop lean and efficient business processes. According to the 2020 Air Cargo Sustainability survey, respondents are said to care more about digital transformation than before, and about 60% now have a digital transformation plan (TIACA, 2021).

Regarding the sector's regulatory authorities, given the likelihood of future emergencies like pandemics, both the United Nations Economic Commission for Europe (UNECE) and the International Civil Aviation Organization (ICAO) aim to facilitate contactless global air movements by preparing digital air cargo technical specifications for safer and sustainable supply chains (UNECE, 2022). For

example, one of the air cargo industry's important actors, Lufthansa Cargo, considers digitalization and sustainability to be the key elements deciding its future. More specifically, using digitalization, a series of physical transformation tools, such as container tracking and management of customer/stakeholder relations, especially to reduce the time needed for document circulation, will enable innovation, efficiency, and sustainability (John and Ayaj, 2021). Polar Air Cargo, which has the vision of becoming the world's most sustainable cargo airline, also uses digital tools to achieve one its sustainability goals, namely its "paperless promise" (Polar Air Cargo, 2021). The digital air cargo reservation platform CargoAi has also developed an innovative digital tool. This helps users analyse the impact of their business's emissions by calculating and reporting the CO2 emissions of every shipment by each route and airline (Brett, 2021).

Paprocki (2021) highlights the importance of digital technologies and innovative solutions for the transportation sector in general, especially regarding climate policy. Chung et al. (2020) offer a radical proposal of using the sharing economy to provide added value through the optimum use of idle aircraft and aircraft loading areas while the integration of Internet of things (IoT) and blockchain applications can improve data security. A summary of the literature review is presented in Table 1.

Author(s), year	**Aim of study**	**Key concepts**
Baffoe and Luo, 2021	Sustainability of humanitarian logistics	Digital business ecosystem
Bartle et al., 2021	Sustainability of air freight/logistics	Sustainable development
Barykin et al., 2021	Integration of digital logistics and marketing approach	Digital platforms
Bavrin et al., 2021	Impact of digitalization on logistics	Digitalization and automated systems
Choi et al., 2019	Global supply chain risk with air logistics	Blockchain
Chung et al., 2020	Data science and analytics in aviation studies	Data science and advanced technologies
Di Vaio et al., 2020	Supply chain management for sustainable performance	Blockchain
Guimarans et al., 2019	Sustainability in aviation	Efficient management
Kelemen et al., 2020	Educational information model for sustainable air transport	Airports
Li, 2020	SWOT analysis of China's air cargo sector	e-commerce and digital logistics
Ordieres-Mere et al., 2020	Sustainability with integration of digital transformation	Digital transformation and Industry 4.0
Paprocki, 2021	Business model proposal to reduce the emission	Virtual airport and digital technologies
Portapas et al., 2021	Proposed system for flexible, environmentally friendly transport	e-VTOL and autonomous zero-emission vehicles
Wu and Yang, 2021	Drivers and strategies of sustainable aviation logistics	Data-driven analytics

Table 1. Summary of Literature Review

Although the number of studies investigating the link between sustainability and digitalization in air logistics is limited, the findings clearly indicate that the field has considerable potential. Thus, it is useful as a reference for future research to identify the common points in these studies. Accordingly, we conducted a bibliographic analysis. The following sections present the method and the findings.

3. Research methodology

In this study, we focused on academic research studies on the integration of sustainability and digitalization in air logistics operations to address the gap of knowledge in the field and propose future research directions. To do so, we followed the five-stage research methodology shown in Figure 1.

Figure 1. Research flow

The first stage involves conducting a literature review of studies of sustainable and digital air logistics. In this study, recent studies directly related to the selected field were reviewed to reveal any gaps in knowledge. The second stage involves selection of keywords to represents the area. In this study, the selected key words were "sustainable", "digital", "logistics, and "air OR aviation". The keyword search was conducted in the commonly used, multidisciplinary SCOPUS database. The third stage involves analysis of the search results to identify current research trends in terms of publication years, subject area, paper type, etc. and guide the future research. The fourth stage is bibliometric analysis, conducted in this study using the VOSViewer program. VOSViewer creates maps for visualizing and exploring network data. Although it is mainly designed for bibliometric network analysis, the software can be used for any type of network data (Eck and Waltman, 2013). The final stage involves identifying future research directions based on the results of the bibliometric analysis, in this case for sustainable and digitalized air logistics.

4. Findings

The findings are presented in two sections. The first part gives the results of the database search to show current research trends in the field while the second part, gives the bibliometric analysis results.

4.1 Current research trends

As mentioned in the previous section, current research trends were identified from a keyword search of the SCOPUS database. Studies were filtered using the following search string: ((TITLE-ABS-KEY (sustainable) AND TITLE-ABS-KEY (digital) AND TITLE-ABS-KEY (logistics))) AND (air OR aviation). To gain a deeper understanding, studies were not filtered by year of publication or research subject. The search identified 41 potential studies to use for identifying current research trends and for the bibliometric analysis.

Regarding publication year (see Figure 2), over half were conducted after 2020, and it is expected that the number of studies will increase in 2022.

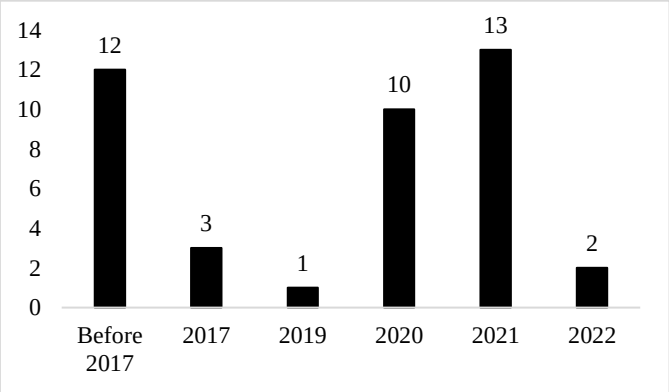

Figure 2. Year of Publication

Regarding the type of studies (see Figure 3), 34% were articles while 32% were conference papers. There were also review papers and conference reviews but few books or book chapters. This may indicate a more detailed theoretical knowledge gap in the field.

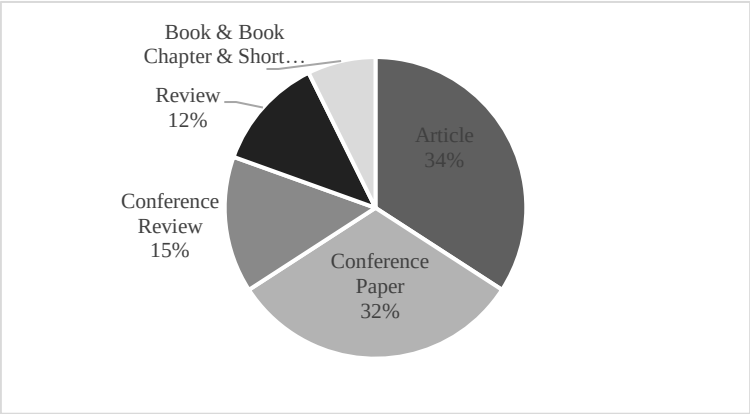

Figure 3. Type of Study

The 41 studies covered various academic disciplines (see Figure 4). The most common field was engineering (30% of studies), followed by energy (18%) and environmental science (16%). For this study, business management and accounting were categorized separately from other social sciences. The results indicate that more studies are essential, especially by social science and managerial researchers.

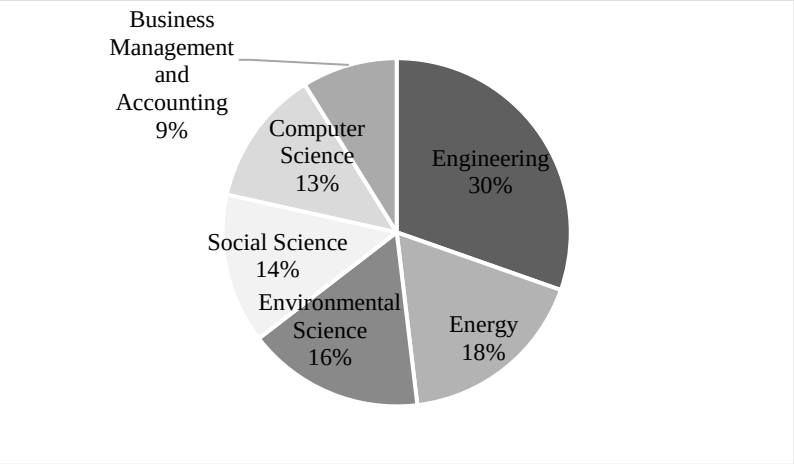

Figure 4. Academic Discipline

The sources in which the studies were published provided further indication of current research trends. Figure 5 identifies the sources that published at least three studies while the remaining sources are grouped in the "others" category. The results show that 10% of the studies were published in Sustainability Switzerland Journal, which is indexed in Web of Science, followed by Advanced Materials Research, International Journal of Production Research, and Applied Mechanics and Materials. The studies in the "other" category were mostly conference papers.

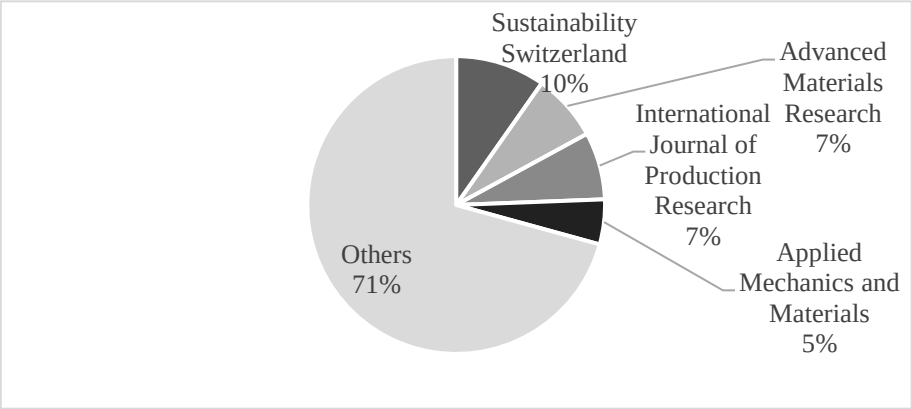

Figure 5. Source Titles

Regarding the geographical distributions of authors, the countries coloured in Figure 6 indicate that a wide range of countries are represented in these studies.

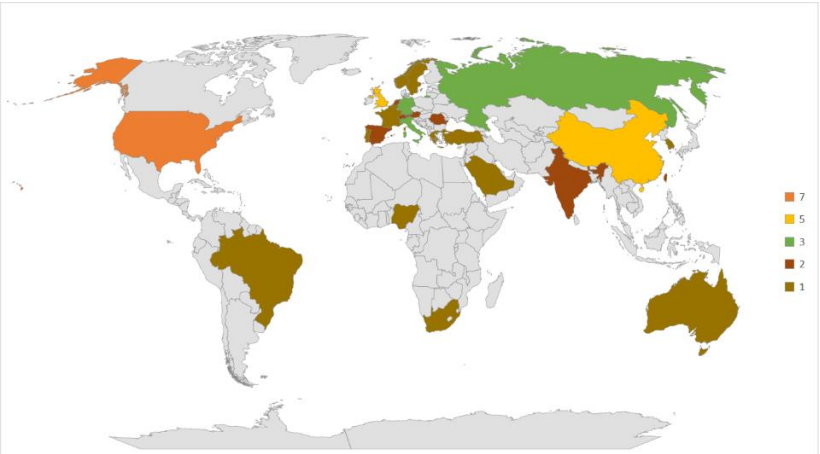

Figure 6. Geographical Distribution of Authors

However, the largest number of authors came from the United States, followed by China and the United Kingdom.

Regarding the methodologies of the current studies in the field (see Figure 7), the majority were theoretical, with desk research, such as proposing frameworks or presenting theoretical models, being the most common. These were followed by studies conducting systematic reviews or secondary data analysis while there were also a few surveys and case studies. Other qualitative techniques used included SWOT analysis and semi-structured interviews while other quantitative techniques included discrete event simulation, multi-criteria-decision making methods, and structured equation modelling.

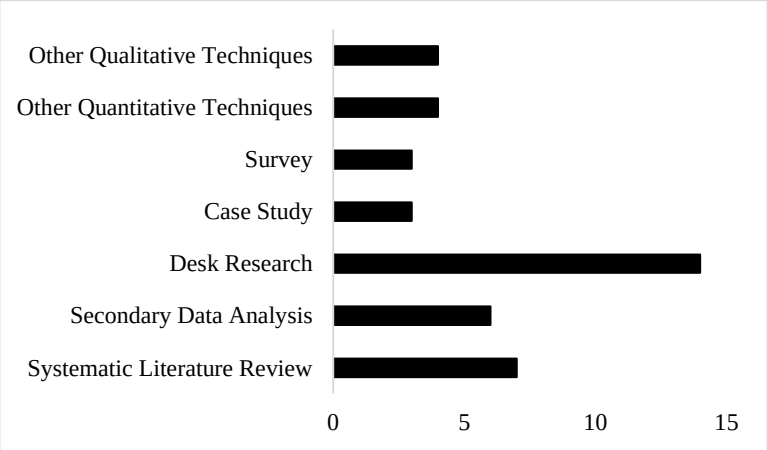

Figure 7. Methodological Approaches

The following section presents the bibliometric analysis of the 41 studies.

4.2 Bibliometric analysis

Bibliometric analysis, also called science mapping, is a method to visualize bibliometric research outputs and a powerful tool for analysing bibliographic networks (Van Eck & Waltman, 2014). Of the various approaches available for conducting bibliographic analysis, co-occurrence analysis and co-authorship networks were applied in the present study using Vosviewer.

The Vosviewer map shown in Figure 8 was created with 51 of the most meaningful co-occurrences from the 601 keywords identified from the 41 studies. In this map, keywords (items) are represented by circles while closely related items are colour coded to represent a cluster (Van Eck & Waltman, 2014). The size of the items represents the weight of the keywords while the lines between items represent their inter-relationships, with the proximity of items or sets indicating the strength of their relationship (Van Eck & Waltman, 2013). Table 2 presents the 19 items (keywords) with the highest weightings and strongest relations.

Items (Keywords)	Occurrences	Total Link Strength
Sustainable Development	20	82
Digital Storage	7	33
Sustainability	6	16
Carbon Footprint	4	28
Environmental Sustainability	4	28
Supply Chains	4	26
Automation	4	21
Decision Making	4	20
Blockchain	4	18
Digital Twin	4	17
Environmental Technology	3	19
Life Cycle	3	19
Information Management	3	18
Freight Transportation	3	16
Digital Transformation	3	14
Industry 4.0	3	12
Planning	3	10
Smart City	3	8
Logistics	3	6

Table 2. Frequencies and Values of Selected Items (Keywords)

As Figure 8 shows, the keywords fell into five clusters, coloured purple, red, yellow, green, and blue. The purple cluster was the weakest with only five items whereas the red cluster, with fourteen items, was the most crowded cluster. Regarding the weight of the items, yellow was the strongest cluster with thirteen items.

Regarding each cluster, the purple cluster revealed several interesting features. First, the only item related to aviation identified in the analysis was "air transportation". This was included in the purple cluster and directly related to "sustainable development". Second, the inclusion of "China and Covid-19" as an item indicates the world's focus during the previous two years. Third, it is notable that "marketing" is closely related to "digital logistics", "sustainable development" and "Industry 4.0". This indicates that, apart from technical and operational processes, marketing is an important key to sustainability.

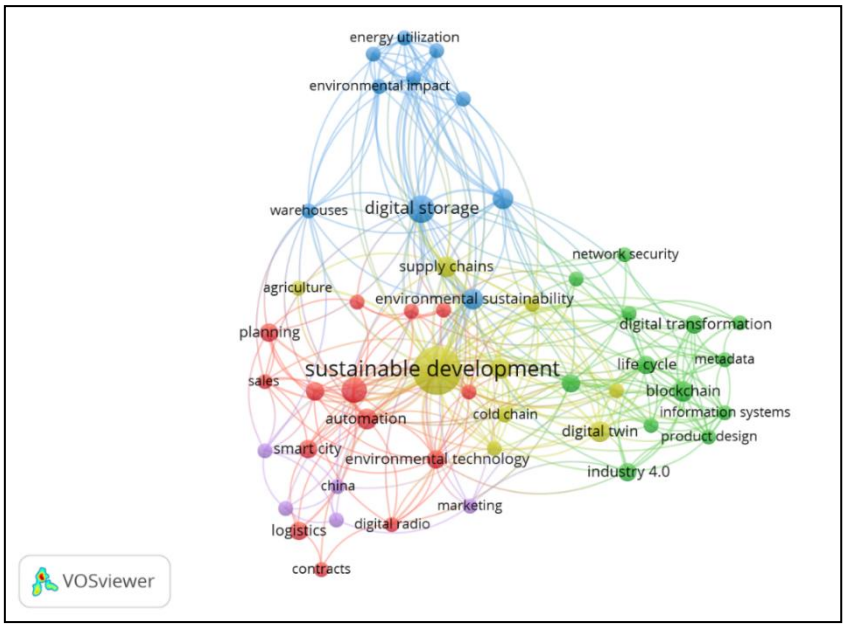

Figure 8. Co-occurrence Analysis of 41 Selected Studies

The red cluster includes items related to transformation processes, such as "digitalization", "automation", and "smart city". Reflecting the elements that most concern the transportation and logistics sector, "energy" and "fuel consumption" were also included.

The blue colour contained items revealing the environmental importance of sustainability, with keywords such as "carbon footprint", "greenhouse gases", "energy utilization", and "environmental impact", which were also related to digitalization through the item "digital storage".

The yellow cluster, which included the item with the highest interaction and weight, "sustainable development", synthesized a wide range of items, such as "quality processes" to "supply chain", from "decision-making processes" to "economic and social effects". It also included "digital twin", showing its relationship to digitalization.

The green cluster included the elements that were the basis of each study, notably "technological evolution", "digital transformation", "blockchain", "metadata", and "Industry 4.0".

To summarize, this bibliometric analysis of the keywords from the 41 studies aimed to reveal which keywords were most prominent regarding sustainability and digitalization in air logistics operations. It identified the following in order of occurrence: "digital logistics" in the purple cluster, "automation" in the red cluster, "digital twin" in the yellow cluster, "digital storage" in the blue cluster, and "digital transformation", "artificial intelligence", "metadata", "blockchain", and "information systems" in the green cluster.

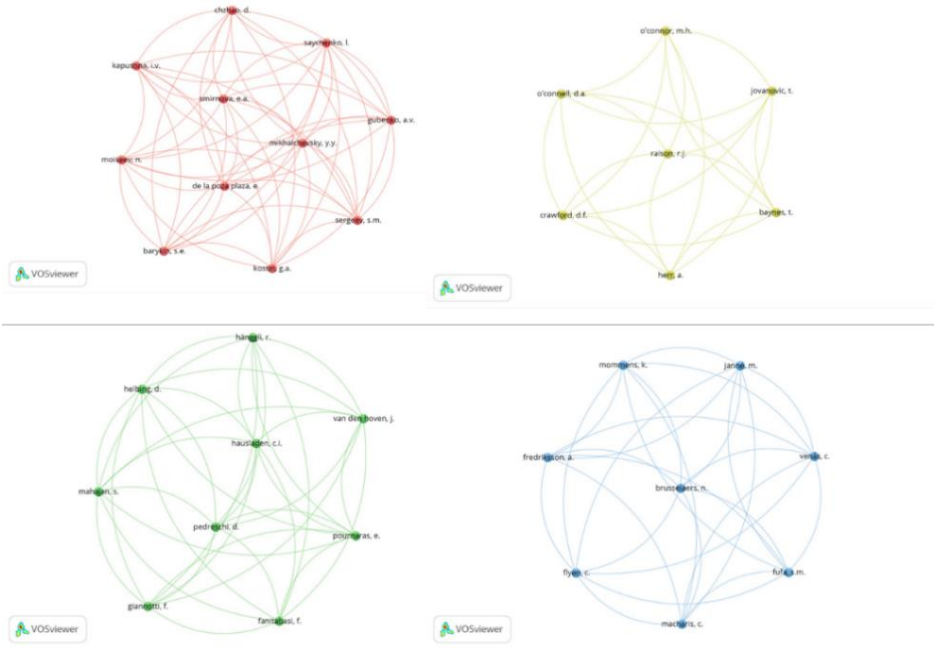

Figure 9. Bibliometric Analysis of Co-Authorships

A bibliometric analysis of co-authorship was also conducted to map which authors have been collaborating in sustainable and digital air logistics research. However, only a few co-authorships were identified due to the limited number of studies.

Figure 9 presents separate co-authorship maps for the four clusters shown in Figure 8. Only links with over seven items were considered in the analysis. The findings show that collaboration between authors across different studies is currently weak in this field. The following section discusses possible future research directions based on these results.

5. Discussion

As explained in the previous section, the bibliometric analysis results showed that current research can be grouped in five clusters. Based on these clusters, the following five research directions can be proposed: sustainable air logistics elements, technical elements, operational elements, environmental elements, and contemporary elements.

Regarding the sustainability element, sustainability is traditionally considered along three dimensions as the environmental, social, and economic triple bottom line (TBL). This could also be useful for analysing air logistics field more holistically. While a few studies have already tried to integrate TBL and digitalization (Braccini and Margherita, 2019; Jayashree et al., 2021), applying these ideas to air logistics could be a promising research area. Other possible research directions could include focusing on resilience and improving the sustainability of air logistics activities.

Regarding operations, future studies can extend in risk management approaches to air logistics activities using data analytics and smart techniques, given that air logistics includes many different risk areas that organizations must deal with.

Regarding technology, blockchain can be used for risk assessment or managing demand-related risks. Research can also focus on producing operational excellence using smart scheduling techniques, which would especially support economic sustainability. Another research direction could be improving technical elements through interdisciplinary research. For instance, digital marketing practices can support social sustainability, thereby increasing both internal and customer satisfaction.

Air logistics activities currently account for around 2% of global CO2 emissions (Gössling et al., 2021), thereby greatly impacting the environment. It is therefore critical to ensure environmental sustainability in this sector. Digital technologies and smart information systems can minimize these negative environmental impacts by balancing energy utilization, minimizing carbon emissions, and eliminating waste. Furthermore, circular approaches can also be integrated with digitalization to create mutual benefits. Thus, future research can focus on digital applications in air logistics to advance environmental sustainability.

Future studies should also consider contemporary issues. In particular, as the bibliometric analysis indicated, the Covid-19 pandemic significantly impacted air logistics operations. New rules, regulations, and standards in the global trade have been implemented. Digital solutions offer a way to meet the challenges caused by the pandemic. For instance, tracking and traceability have become even more important, so improved RFID IoT technologies can be applied to air logistics processes. Thus, in addition to technical implementations, future studies can suggest new frameworks and roadmaps to guide policymakers.

To sum up, besides technical studies, new studies in other directions, especially in business and management science, are essential to ensure a sustainable and digitalized air logistics field. Future studies can also integrate theories and adapt traditional practices to the new environment.

6. Conclusion

Sustainability and digitalization are highly significant topics, especially in operational fields, with the number of studies increasing rapidly. The integration of sustainability and digitalization is also a promising research area in that research into the use of digital technologies to increase sustainability is valuable both theoretically and practically. While Industry 4.0 or digitalization concepts, such as automation, artificial intelligence, and big data, are important for all industries, they were previously somewhat overlooked in the air cargo sector. However, due to global changes, especially during the Covid-19 pandemic, air cargo stakeholders increasingly realize that digitalization is essential for ensuring the sustainability of air cargo supply chains (Kuehne Nagel, 2022). Accordingly, the present study focused on the air logistics industry, which is a significant sector that affects other sectors because of its critical role in a globalized world.

Although sustainable aviation, or sustainable air logistics is a relatively popular research area and digital applications in the air logistics industry are increasing

rapidly, few studies have integrated these concepts. Therefore, by conducting a bibliometric analysis, this study represented an initial attempt to demonstrate the potential of integrating sustainability and digitalization in air logistics. Its main contribution is to reveal a gap in knowledge and indicate future research directions to extend theoretical and practical knowledge in the field. The study also aimed to encourage future research into practical implementations and improve digitalization and sustainability in air logistics.

The lack of studies of air logistics and sustainability limited the available keywords for this study. Nevertheless, the analysis revealed a number of key concepts in sustainable aviation and sustainable logistics. To ensure that air logistics are sustainable, it is critical to consider Industry 4.0 elements from a technical, operational, and environmental perspective. That is, it is meaningless to consider this sustainability from a single perspective because improvements in any individual process will have a knock effect across the supply chain.

In addition to academic studies that produce theoretical knowledge, existing applications in the sector should also be analysed to reveal the air logistics' overall situation. One of the most logical short-term steps to increase sustainability in air logistics would be to reinterpret and transform current problems, such as bottlenecks, and solution proposals in terms of Industry 4.0.

This study revealed that there are many open research areas in sustainable air logistics in the digital era, particularly integrating sustainable development principles with digitalized air logistics operations. Moreover, technology-based applications in air logistics for sustainable practices can be implemented, and new ways of minimizing environmental impacts using digital technologies can be investigated. Finally, new business models for the post-Covid-19 era in air logistics can be developed by integrating sustainability principles and digital technologies.

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