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Drone Delivery Global Research Landscape: A Bibliometric Analysis

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Abstract

Background: Rapid technological advancements have revolutionized research into unmanned aerial vehicles (UAVs), commonly known as drones, particularly in delivery applications. However, despite numerous related publications, there remains a lack of systematic reviews that synthesize challenges, trends and recent advances in drone delivery. To address this gap, the present study conducts a bibliometric analysis to examine evolutionary trends and emerging applications of UAVs between 2015 and 2024.

Objective: This study aims to identify established and emerging trends in drone delivery research by analysing articles, journals, authors, institutions, countries and thematic areas.

Methods: Previous studies are selected using a systematic approach, followed by bibliometric analysis with tools including VOSviewer, Bibliometrix and ScientoPy, which emphasizes key authors, top journals and countries, collaboration patterns and recurring author keywords.

Results: The bibliometric analysis of 1,438 articles from 583 sources authored by 4,333 scholars (2015–2024) reveals a strong interdisciplinary focus in drone delivery research. Military applications largely drove early studies, but recent breakthroughs highlight the integration of artificial intelligence (AI) for autonomous navigation and energy optimization. Emerging themes include the development of drone swarms for scalable applications such as disaster response and agricultural mapping. Geographically, China, the United States and Australia dominate contributions, with extensive international collaborations fostering global innovation. Across journals and authors, the literature reflects a steady evolution from conceptual and technical foundations to applied studies addressing logistics, smart cities and environmental monitoring. Overall, the results suggest that drone delivery research is transitioning from exploratory phases towards AI-enabled autonomy deployment.

Conclusion: Drone delivery research has evolved from military origins into a global, interdisciplinary field driven by AI. China, the USA and Australia are the leading contributors. Its future hinges on balancing technological innovation—such as autonomous navigation and swarm applications—with ethical, regulatory and societal considerations for sustainable integration.

Index Terms

Unmanned aerial vehicles; Smart supply chain drones; Last-mile delivery; Drone delivery; Urban logistics.

1 INTRODUCTION

Modern drones owe their existence to the visionary idea of Serbian American Nikola Tesla. Back in 1898, he unveiled his "teleautomaton" at an electrical exhibition (Wuebben, 2021). The teleautomaton midwifed the revolution of the remote-control concept, applicable to vehicles across air, land and water.

This invention laid the groundwork for the technology powering modern drones (Goldberg, 2015). The concept of using unmanned aerial vehicles (UAVs), commonly known as drones, for delivery has historical origins dating back more than a century, especially within military contexts (Eskandaripour & Boldsaikhan, 2023). Although early drones lacked the sophisticated autonomy seen in their contemporary counterparts, their development significantly contributed to the foundational knowledge for future civilian applications.

Widespread commercial adoption of drones for delivery remained largely dormant until the 21st century. This dormancy can be attributed to technological limitations, particularly in miniaturization, cost-effectiveness and battery life (C. Zhang et al., 2021). Rojas Viloria et al. (2021) categorized drone applications into five distinct classes: military, internal logistics, entertainment, surveillance and data collection, and parcel delivery, with parcel delivery emerging as the dominant category, constituting a significant 41% of all recorded drone applications (Rojas Viloria et al., 2021). The first commercial application of drones for delivery took place in Germany in 2013, when DHL carried out a medical delivery using a drone. This was followed in 2015 with the delivery of medications and essential medical supplies using drones in the USA by Flirtey (F. Li & Kunze, 2023).

The turn of the millennium heralded a new era for drone delivery. Rapid advancements in miniaturization, cost reduction and battery technology significantly expanded the realm of possibilities. Simultaneously, evolving regulatory frameworks created a more permissive environment for commercial drone operations. These factors collectively empowered major corporations such as Amazon, Google, UPS and Zipline to actively explore the potential of drone delivery. Driven by the demand for faster, more efficient and potentially more sustainable delivery solutions, this burgeoning field holds transformative potential for the logistics landscape (Elmeseiry et al., 2021). Drone delivery offers significantly faster delivery times compared to traditional methods, cutting down transit times from days to mere hours or even minutes (Benarbia & Kyamakya, 2021; Eskandaripour & Boldsaikhan, 2023; Macrina et al., 2020). This rapid delivery capability not only enhances customer satisfaction but also enables businesses to streamline their operations. Moreover, drone delivery has the potential to significantly reduce costs associated with transport, fuel and labour, leading to improved efficiency and profitability (Elmeseiry et al., 2021; Ikelu & Ezin, 2020). Similarly, Poikonen et al. (2017) demonstrated that drones operating at 50% greater speed than traditional trucks can reduce delivery completion times by a remarkable 75%.

Notwithstanding their potential for delivery services, drones have safety concerns and technological constraints. Specifically, they have challenges with constrained cargo capacities, limited travel ranges and rigid regulatory frameworks that make it difficult for them to be used effectively in delivery operations (Madani & Ndiaye, 2022). Governments worldwide are grappling with the development and enforcement of regulations to ensure safe and responsible drone operations. These regulations encompass aspects such as flight altitude, payload capacity and airspace restrictions (Emimi et al., 2023). Safety concerns also loom large, particularly regarding the risk of mid-air collisions, accidents during take-off and landing and potential harm to people or property on the ground (Mohsan et al., 2023). Addressing regulation compliance and safety issues adds complexity and costs to drone delivery operations, slowing down progress in the industry. Additionally, issues such as battery life, adverse weather conditions and limited navigation autonomy capabilities are significantly affecting the reach and efficiency of drone delivery. Understanding the trends and impacts of a research domain is essential for guiding strategic research planning, fostering collaboration and informing evidence-based decisions by policymakers, funding agencies and academic institutions. Attaining these necessitates a bibliometric analysis of a given research domain.

Bibliometric analysis has emerged as a crucial tool in the academic circles, offering a quantitative methodological approach for evaluating the impact and trends within various fields. This methodological framework, pioneered by Pritchard (1969), integrates mathematics, statistics and bibliography to provide a comprehensive assessment of publication-based data. By using bibliometric analysis, researchers can probe into diverse aspects such as publication quantity, citation frequency and research outcomes, thereby gaining valuable insights into the progression and evolution of a particular field of study. Moreover, bibliometric analysis facilitates the identification of influential publication sources, authors, institutions and even countries contributing significantly to scientific discourse. The utilization of advanced software such as VOSviewer, Bibliometrix and ScientoPy further enhances the capabilities of bibliometric research by enabling the processing of large datasets, ultimately leading to high-impact research outcomes (Anlesinya & Dadzie, 2023).

This study aims to conduct a comprehensive bibliometric analysis focusing on the utilization of drones for delivery across various sectors. The research aims to identify both established and emerging trends within articles, journals,

authors, institutions and countries related to the application of drones for delivery purposes. To achieve these objectives, the following research questions are formulated:

- **RQ1:** What are the global publication trends and geographical distribution patterns in drone delivery research?
- **RQ2:** Which journals serve as the main outlets for drone delivery publications and what is their relative impact?
- **RQ3:** Which authors and institutions are the most influential contributors to drone delivery research and how do they collaborate?
- **RQ4:** What are the most cited articles shaping the intellectual and practical foundations of drone delivery research?
- **RQ5:** What thematic areas and emerging trends can be identified through keyword co-occurrence and thematic mapping?

The rest of this paper is organized as follows: Section 2 provides a literature review of related works; Section 3 outlines the methodology employed for bibliometric analysis; Section 4 presents the research findings along with their implications; emerging trends in drone delivery are discussed in Section 5; and finally, Section 6 concludes and provides insights into the current state of drone delivery research.

2 LITERATURE REVIEW

In this section, literature related to drone delivery is reviewed with the intent of establishing what has been done so far in research into drone delivery, while providing an overview of existing literature related to drone delivery. It delves into previous studies and research efforts that have explored the utilization of drones for delivery purposes across various sectors. This section aims to contextualize the current study within the broader research landscape, highlighting key findings, methodologies and gaps identified in previous bibliometric analyses and scientific literature reviews related to drone delivery. Table 1 gives a summary of the related literature, including the authors, title, focus, database, search string software, method, number of articles reviewed, findings and gaps.

Table 1. *Review of related works.*

Author	Title	Focus	Database	Search string	Software	Method	Articles reviewed	Findings	Gaps
Cesur et al. (2022)	A Bibliometric Analysis of Empirical Studies on Drone Delivery	Consumers' intention and attitude towards drone delivery	Google Scholar	"drone delivery" OR "product delivery by drone" AND "perceived" OR "attitude" OR "empirical"	VOSviewer	Bibliometric	30	Increasing attention towards drone delivery among researchers	Focussed on user intention rather than drone application
Madani & Ndiaye (2022)	Optimization of Hybrid Truck-Drone Delivery Systems: A bibliometric analysis	Hybrid truck-drone delivery optimization models	Scopus	(("truck" OR "vehicle") AND ("drone" OR "unmanned aerial vehicle" OR "UAV") AND ("last mile" OR "delivery" OR "logistics") AND "rout*"))	VOSviewer and MS-Excel	Bibliometric	98	More attention is paid to the cost aspect, with less consideration of environmental and social factors and less emphasis on optimization.	Focuses only on the routing problem
Pulsiri & Vatananan-Thesenvitz (2021)	Drones in Emergency Medical Services: A Systematic Literature Review with Bibliometric Analysis	Drones in medical emergency delivery	Scopus	(drone OR UAV) AND (medic* AND service*)	VOSviewer	Systematic literature review, bibliometric analysis	40	Drones play a crucial role in EMS, especially during the COVID-19 pandemic	Focus on EMS
Chauhan (2019)	Scholarly Output on Drone Research: A	Global research output on drones over 50	Scopus	Not specified	MS Excel	Bibliometric analysis of publication	Not specified	Observed publication and citation growth	Lack of focus on drone delivery and

Author	Title	Focus	Database	Search string	Software	Method	Articles reviewed	Findings	Gaps
	Bibliometric Study	years, including delivery applications				and citation data		rate of drone research	limited insights into thematic trends and emerging research
Román-Piedra et al. (2023)	Advances in Research on the Use of Drones in Production and Transport Engineering in the Hydrocarbons Industry: A Bibliometric Analysis	Application of drones in production & transport processes in hydrocarbons industry	Scopus & Web of Science	(("petroleum industry*") OR ("hydrocarbon industry*") OR ("oil industry*") OR ("gas industry*") OR ("petroleum pipeline industry*") AND (("remote pilot aircraft system*") OR ("RPAs*") OR ("drone*") OR ("UAVs*") OR ("unmanned aerial vehicle*"))	VOSviewer, bibliometric software	Bibliometric analysis, systematic review (PRISMA), case study evaluation	143 (1985–2023)	Increasing trend of drone use for safety, pipeline/storage tank inspection and environmental monitoring.	Few standard protocols for drone-based inspections in hydrocarbon processes
Rejeb et al. (2023)	Drones for Supply Chain Management and Logistics: A Review and Research Agenda	Application of drones in supply chain management and logistics, including potentials, challenges and future research directions	Scopus	(drone* OR "unmanned aerial vehicle*" OR uav* OR "unmanned aircraft system*" OR uas* OR "remotely piloted aircraft*") AND ("supply chain*" OR logistic*)	Not explicitly specified	Systematic literature review, descriptive analysis, backward snowballing, thematic analysis	55 (2015–2020).	Drones are increasingly adopted in logistics for last-mile delivery, inventory management and disaster relief.	Absence of comprehensive coverage of emerging drone applications such as swarming and AI integration.

Drone delivery research has progressed into a multidisciplinary domain, spanning logistics, information systems, smart cities and technology management. In recent years, drone delivery research has shifted from exploratory analyses of technological feasibility to systematic examinations of operational efficiency, user acceptance and policy integration. A consensus across bibliometric reviews (Cesur et al., 2022; Chauhan, 2019; Madani & Ndiaye, 2022; Pulsiri & Vatananan-Thesenvitz, 2021; Rejeb et al., 2023; Román-Piedra et al., 2023) indicates that the field is rapidly growing, with a notable concentration of studies in logistics and supply chain contexts and growing diversification into emergency response and industrial applications.

A clear thematic trend in the literature centres on last-mile delivery optimization. Drones are increasingly positioned as viable complements or alternatives to traditional logistics vehicles, primarily due to their capacity to reduce costs, emissions and delivery times in both urban and remote regions. The emergence of hybrid truck-drones exemplifies this trend, aiming to address the "last 50 metres" challenge in e-commerce and humanitarian logistics (Madani & Ndiaye, 2022; Rejeb et al., 2023). Despite their operational promise, current research identifies persistent limitations related to battery life, payload capacity and the absence of standardized airspace regulations as some of the factors constraining scalability and cost-efficiency (Emad Alfaris et al., 2024; Moshref-Javadi et al., 2020).

From a behavioural viewpoint, studies consistently demonstrate that consumer acceptance and perceived risk are central determinants of drone delivery adoption. Research employing frameworks such as the technology acceptance model (TAM) and unified theory of acceptance and use of technology (UTAUT) finds that perceived usefulness, effort expectancy and social influence positively shape adoption intentions, whereas risk perceptions regarding privacy, safety and noise present strong inhibiting effects (Kim & Hwang, 2020). This behavioural

dimension is especially salient in cross-cultural analyses, showing that social context, digital literacy and regulatory environments moderate consumer readiness (Cesur et al., 2022; Yoo et al., 2018).

At the operational and technical level, researchers have advanced optimization and simulation models that enhance route efficiency and delivery reliability. Recent developments in artificial intelligence and reinforcement learning have introduced adaptive navigation algorithms capable of real-time collision avoidance and dynamic routing in urban environments (Farsath et al., 2024; Kuo, 2024). Such innovations mark a shift from conceptual modelling towards autonomous, data-driven logistics systems, linking engineering design with behavioural insights to foster safer and more reliable delivery operations.

Beyond logistics, drone technology is increasingly recognized for its role in emergency medical services (EMS) and industrial monitoring. Within EMS, drones contribute to rapid medical supply delivery, blood transport and situational awareness in disaster response applications, which became particularly visible during the COVID-19 pandemic (Pulsiri & Vatananan-Thesenvitz, 2021). In industrial sectors, especially construction and environmental management, drones equipped with LiDAR, infrared and methane detection sensors have proven effective in pipeline inspection and emission monitoring (Román-Piedra et al., 2023). These applications extend drone utility beyond logistics into safety, sustainability and environmental governance.

Across these domains, methodological convergence is evident. Most bibliometric studies rely on Scopus-indexed datasets and analytical tools such as VOSviewer, enabling mapping of publication trends, author collaborations and thematic clusters (Cesur et al., 2022; Chauhan, 2019). This methodological consistency reinforces the robustness of knowledge synthesis while also highlighting geographical concentration, with strong empirical contributions from Chinese and South Korean researchers and the need for broader international engagement. The literature review illustrates a maturing research field characterized by an operational focus on system optimization, a behavioural focus on consumer perception and acceptance and an expanding application scope across humanitarian and industrial settings. However, integration between these dimensions remains limited. Future research should thus emphasize interdisciplinary frameworks that unite behavioural, technical and regulatory insights to support scalable, sustainable and socially accepted drone delivery ecosystems.

As evident from the reviewed work, over 80% of the research is based on the Scopus database and utilizes VOSviewer for analysis. Scopus is the most widely used data source for bibliometric analysis due to its vast collection of abstracts and citations, which includes a vast range of regional and international scientific journals, conference proceedings and books; thus, Scopus was chosen for this bibliometric analysis. The accuracy of author and institution profiles is guaranteed by the stringent content selection, ongoing quality assurance procedures, advanced profiling algorithms and manual curation of the database. As a result, Scopus is a trustworthy source for extensive research reviews, evaluations of science policies and university rankings. Its accurate and comprehensive metadata make it a popular option for bibliometric research and quantitative science studies (Baas et al., 2020).

Our work, distinct from these studies, comprehensively examines all facets of drone delivery research, providing valuable insights for researchers, practitioners and policymakers alike.

3 MATERIALS AND METHODS

Bibliometric analysis plays a pivotal role in systematic literature reviews by overcoming limitations associated with traditional narrative reviews (Linnenluecke et al., 2020). Unlike narrative reviews, which may suffer from bias and lack of rigor due to limited data processing capacities, bibliometric analysis allows comprehensive literature searches across scientific disciplines. This approach not only ensures a more exhaustive review process but also enhances the quality and reliability of literature reviews through its quantitative methodology. By synthesizing large volumes of data, bibliometric research not only presents the current state of research but also identifies emerging trends, thereby aiding scholars in making informed decisions and contributing to the advancement of scientific knowledge. Therefore, the significance of bibliometric analysis lies in its ability to offer a holistic view of research landscapes, enabling researchers to navigate through vast amounts of information efficiently and derive meaningful conclusions for further scholarly exploration (Lim et al., 2022). Following the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) methodology to synthesize current knowledge, the methodology of this work consists of three stages: identification, screening and inclusion (Zakaria et al., 2021) as depicted in Figure 1.

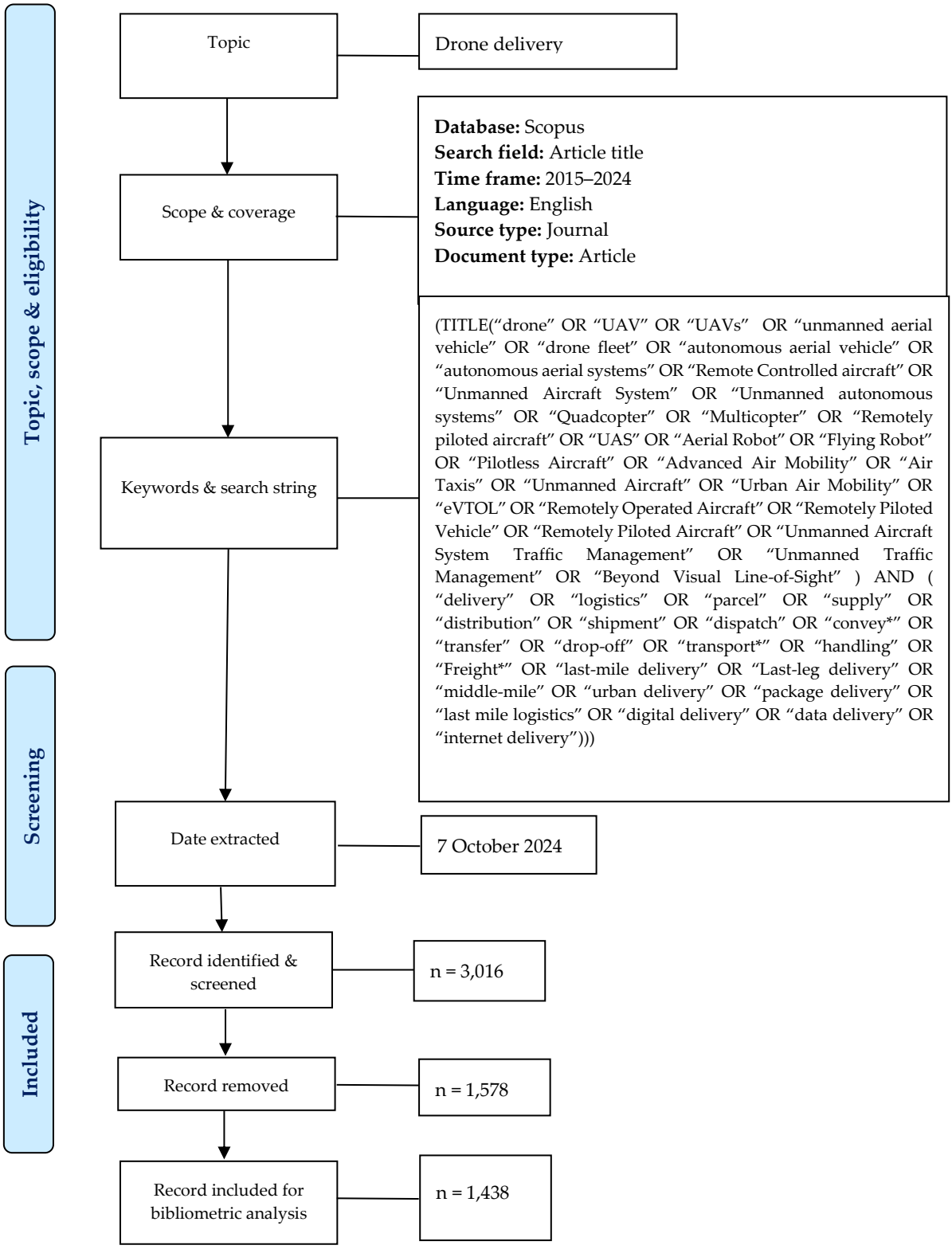

Figure 1. *PRISMA Flow diagram of the search strategy.*

3.1 Identification

In the identification stage, potential sources of articles, journals and other related sources relevant to the study are identified. The publication dataset for this study is obtained from the Scopus database to thoroughly analyse global research developments and patterns in drone delivery research. Following the data source identification comes keyword selection. After numerous iterations, keywords relevant to the research field were formulated to find

relevant publications in the Scopus database. The required data were extracted using the formulated search string as follows:

(TITLE("drone" OR "UAV" OR "UAVs" OR "unmanned aerial vehicle" OR "drone fleet" OR "autonomous aerial vehicle" OR "autonomous aerial systems" OR "Remote Controlled aircraft" OR "Unmanned Aircraft System" OR "Unmanned autonomous systems" OR "Quadcopter" OR "Multicopter" OR "Remotely piloted aircraft" OR "UAS" OR "Aerial Robot" OR "Flying Robot" OR "Pilotless Aircraft" OR "Advanced Air Mobility" OR "Air Taxis" OR "Unmanned Aircraft" OR "Urban Air Mobility" OR "eVTOL" OR "Remotely Operated Aircraft" OR "Remotely Piloted Vehicle" OR "Remotely Piloted Aircraft" OR "Unmanned Aircraft System Traffic Management" OR "Unmanned Traffic Management" OR "Beyond Visual Line-of-Sight") AND ("delivery" OR "logistics" OR "parcel" OR "supply" OR "distribution" OR "shipment" OR "dispatch" OR "convey*" OR "transfer" OR "drop-off" OR "transport*" OR "handling" OR "Freight*" OR "last-mile delivery" OR "Last-leg delivery" OR "middle-mile" OR "urban delivery" OR "package delivery" OR "last mile logistics" OR "digital delivery" OR "data delivery" OR "internet delivery"))). The search for and download of the final bibliometric data from Scopus was completed on 7 October 2024.

3.2 Screening

Based on the search string, 3,016 documents were retrieved from the Scopus database from 1965 to 2024 (7 October 2024). Of the 3,016 retrieved documents, 1,045 (34.65%) are classified as open access. The open-access publications were further categorized into Gold (654), Hybrid Gold (104), Bronze (98) and Green (309). The majority of the publications indexed in the Scopus database were written in English (2,852: 94.56%), with smaller numbers in other languages such as Chinese (128), Croatian (1), Dutch (1), German (9), Japanese (10), Korean (8), Polish (1), Spanish (5), Turkish (1), Ukrainian (1) and undefined (1). The documents were spread across different subject areas, including prominent fields such as engineering (1,837), computer science (1,550), mathematics (560), social sciences (330) and decision science (303). The search strings were later refined by limiting the documents to articles in English and those published from 2015 to 7October 2024. The refinement process brought the total number of publications to be considered for analysis down from 3,016 to 1,438.

3.3 Inclusion

From the screening stage, a total of 1,438 articles were identified to be pertinent to the study. The identified articles are further subjected to scrutiny aimed at determining their relevance to the study objective. This stage is critical for ensuring that only studies meeting all predefined criteria are synthesized and reported.

3.4 Visualisation mapping using VOSviewer, ScientoPy and Biblioshiny

3.4.1 VOSviewer

VOSviewer was created by Nees Jan van Eck and Ludo Waltman of Leiden University's Centre for Science and Technology Studies (CWTS) and was formally published in the article "Software survey: VOSviewer, a computer program for bibliometric mapping" published in Scientometrics (Van Eck & Waltman, 2010). VOSviewer is compatible with bibliometric data downloaded from WoS, Scopus, Dimensions, PubMed and RIS format. VOSviewer can import and export data from various sources, featuring excellent visualisation options, including network, overlay and density views. It also offers the ability to save all generated maps in different graphical file formats, such as bitmap or vector. Equally, VOSviewer can be launched either directly from the web page or through desktop installation. The limitation of VOSviewer is a lack of preprocessing, analytical and support for statistical analysis, data cleaning or reproducible workflows (Van Eck & Waltman, 2010). Its use is limited to in-depth or automated bibliometric studies due to its limited temporal analysis, limited scripting options and weaker integration with quantitative network metrics compared to ScientoPy and Biblioshiny (Aria & Cuccurullo, 2017; Börner et al., 2007).

3.4.2 ScientoPy

ScientoPy is a graphical user interface (GUI) bibliometric analysis tool developed in Python. The interface consists of two main tabs: preprocessing and analysis. In the preprocessing tab, activities such as document type filtering,

duplicate removal, authors' name normalisation, times cited and document country and institutions can be performed. The analysis tab allows activities that include performing top and specific topic evaluations and wildcard searches. *ScientoPy* contains some performance indicators that include the average growth rate, average documents per year and percentage of documents in the last years. However, the downside of this tool is the lack of provision for sophisticated maps, with visualisation choices such as timeline, horizontal bars, horizontal bars trends, evolution and word cloud. Plotted graphs can be exported in different formats, such as EPS, SVG and PNG (Moral-Muñoz et al., 2020).

3.4.3 Biblioshiny

Biblioshiny is a user-friendly bibliometric analysis tool powered by Bibliometrix and developed in the R package. It provides a web-based interface that simplifies the process of extracting insights from large research datasets, enabling researchers to explore and visualise bibliometric data without the need for coding (Aria & Cuccurullo, 2017). Biblioshiny works well with popular bibliometric databases such as WoS, Scopus and Dimensions. Compatible input data formats are RIS and CVS, while output formats include RIS, CVS and PNG. Biblioshiny is valuable for researchers across various fields due to its slick design, organised menus and comprehensive analysis options. The platform offers a wide range of analytical tools, including metrics for sources, authors and documents, as well as visualisations of conceptual, intellectual and social structures (Moral-Muñoz et al., 2020). Biblioshiny lacks the scalability and sophisticated dynamic network analysis of ScientoPy, which makes it less appropriate for extensive or intricate bibliometric research (Börner et al., 2010).

4 RESULTS AND DISCUSSION

4.1 Global publication trends and geographical distribution patterns in drone delivery research

4.1.1 Publication and citation trends

Figure 2 shows the key snapshot of academic research trends on bibliometric data on drone delivery from 2015 to 2024 obtained from the Scopus database. The bibliometric data were extracted from 1,438 documents from 583 sources spanning the period 2015–2024, with a robust annual growth rate of 47.82%. In total, 4,333 authors were involved in the research, of which 53 were single authors, while the rest represented an average of 4.52 co-authors per document, indicating strong collaborative efforts. Notably, 31.43% of the authors are involved in international collaborations showing global research partnerships. The documents cited 55,692 references in total, with each document having an average age of 2.18 years and getting an average of 22.73 citations. Furthermore, the unique keywords used by authors amounted to 4,169, underlining the variety of research topics. The vibrant and interrelated landscape of current academic research, as elucidated by the data, underscores the substantial growth, collaboration and impact of the authors of drone delivery research.

Figure 2. *Snapshot of bibliometric data on drone delivery.*

The publications and citation trends of drone delivery research between 2015 and 2024 are displayed in Figure 3. The figure shows a steady increase in the number of publications over the years, from 10 in 2015 to 337 in 2024,

indicating growing research activity in the drone delivery domain. This trend suggests that the topic has gained significant interest and advancement within the academic community. The early period between 2015 and 2019 saw moderate growth in the publication rate from 10 in 2015 to 78 in 2019. From 2020, drone delivery research appears to have gained momentum, as evidenced by the substantial growth in the volume of publications, which almost doubled from 78 in 2019 to 139 in 2020. This growth trend continues, reaching its peak in 2024 with a total of 337 publications, even though the data for the year are not complete.

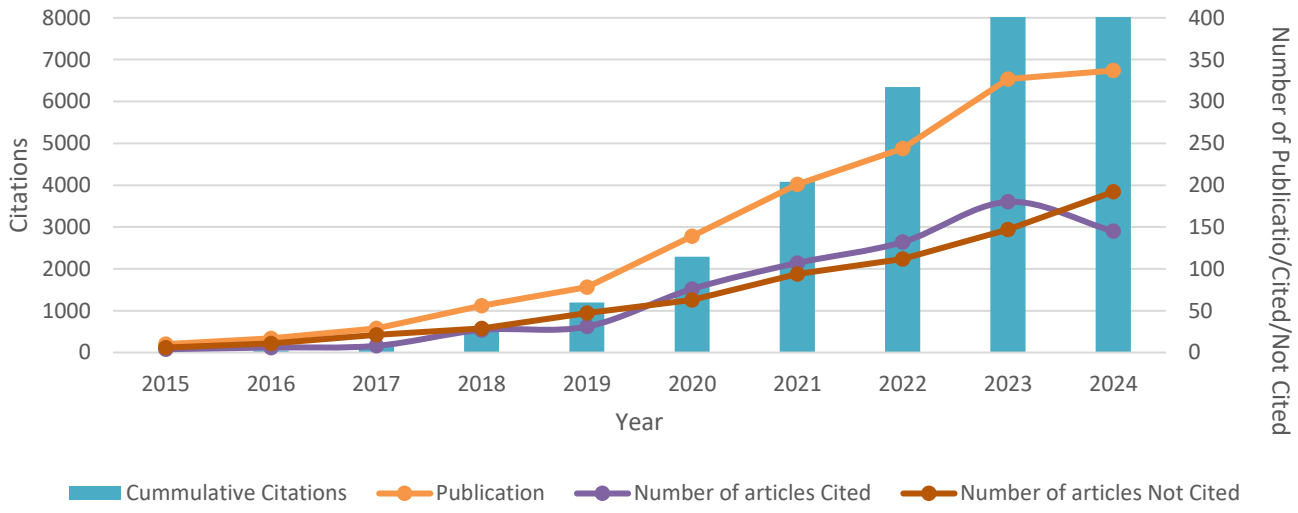

Figure 3. *Citations and Publications Trends from 2015 to 2024.*

As for the cumulative citations, there is a sharp and consistent increase from 7 in 2015, crossing the 4-digit mark to 1,195 in 2019, and reaching a high of 7,726 citations in 2024, indicating that research into drone delivery has attracted significant attention of researchers over the last decade. Notably, after 2018, the citation rate grew proportionately to the increase in publications. This suggests that the newly published articles were swiftly generating enormous scholarly discussions and contributing to ongoing research discourse.

The early period saw a low number of cited articles, with 3, 6 and 8 articles cited in the years 2015, 2016 and 2017, respectively. This trend changed from 2018 onward, with a significant rise in the numbers of articles cited. A total of 27 articles received citations in 2018, and this rose consistently across the years, reaching a climax in 2023 with 180 articles receiving citations. However, 2024 saw a decline in the citation rate to 145. This is likely because the data for the year are not complete. Research in the early stage (2015–2019) might represent the exploratory phase, whereas the later stage (2020–2024) represents the established and relevant phase of drone delivery in the academic and industrial community. This trend signifies the maturity of drone delivery research.
Expectedly, many uncited articles exist in the period under review. As evident in Figure 3, there is an exponential increase in the number of uncited articles over the years, coinciding with the rise in publications. The period between 2015 and 2019 saw a consistent rise in the number of uncited articles relative to the publication (ratio), peaking at 0.6 in 2019. This may be due to the quality of the articles, lack of research interest or saturation of specific topics. Conversely, the ratio of uncited articles showed a downward trend from 2020, reaching a low of 0.45 in 2023. The decline in the ratio of uncited articles may be due to the impact of COVID-19 and the post-COVID era having a motivating effect on drone delivery research and/or possibly an increase in funding and publications of more influential articles.

Summarily, the steady rise in publications indicates a growing attention to drone delivery research, signifying its relevance and importance, while the rapid growth in citations per publication signifies the impact of the research into drone delivery. Figure 3 also reveals the correlation between publications and citations, indicating a positive feedback loop in which increased publications result in a corresponding increase in citations, consequently spurring further research.

The H-index measures the impact and productivity of researchers in a given research domain (Persad-Paisley et al., 2024). Based on the citation overview of the 1,438 documents in the Scopus database, the H-index is 86. This implies

that out of the 1,438 articles under consideration, 86 have been cited at least 86 times. Out of the publications identified, 722 had not been cited, while 209 articles published between 2015 and 2019 had not received any citations. As for the articles published between 2020 and 2024, 608 publications had not been cited, with the majority being from 2024 (192 publications). The recency of the publications induces unfamiliarity among researchers or a lack of popularity within the scientific community, which might account for the poor citations. Between 2015 and 2024, the number of articles receiving single-digit citations varied widely. In 2015, out of the 10 papers, 4 had got citations, while in subsequent years, the numbers increased gradually, peaking in 2023 with 180 documents. A decline to 145 documents is witnessed in 2024, probably due to the recency of the publications and the fact that the year had not ended.

The year with the fewest cited papers is 2015, with only 4 articles receiving citations. The year 2023 has the highest number of cited articles that received citations, with 180 articles cited. Although 2024 had not ended, it has the second-highest number of documents receiving citations, amounting to 145. This trend suggests a consistent increase in both the publications and citation rates over the years. The number of publications across years with double-digit and triple-digit citations varies considerably. Over the years, several publications have garnered significant attention, receiving substantial numbers of citations. For instance, the period 2020–2024 saw four notable publications receiving citations in the triple digits (107–180), indicating a high level of impact and recognition within the academic community. Equally, the period 2015–2019 saw most publications receiving lower citation counts, ranging from 0 to 76, suggesting a more modest level of impact. The dynamism of academic research and the fluctuating effects that publications can achieve over time are manifestations of the variation in citation counts across different years.

These data reflect a highly dynamic and rapidly expanding research field. While there are minor fluctuations in 2024, the general trends from 2015 to 2023 indicate significant growth in both publication output and scholarly influence. As the number of publications increased, their impact, as measured by citations, also grew exponentially, showing the increasing relevance of the research. If the field can sustain this level of innovation and relevance, these trends will likely continue in the future, albeit with natural fluctuations.

4.1.2 Geographical distribution and leading countries

Drone delivery research is spread unevenly across the globe, with 90 countries generating publications and citations. Based on Figure 4A, which shows the global publication figures, the drone delivery research landscape between 2015 and 2024 is dominated by Asia, with active involvement of 29 countries generating 1,012 publications. China is leading the other countries in Asia, having the highest number of publications (473). Asia's dominance in drone delivery research is driven by a combination of technological advancements, government policy and regulation, economic and market factors and dense urban populations, driving a rapid adoption rate (C. Chen et al., 2022; Raj & Sah, 2019; Schaarschmidt et al., 2021). Other Asian countries making significant contributions include South Korea, India and Japan, with 107, 84 and 44 publications, respectively.

Europe came a distant second with 32 countries engaging in drone delivery research, resulting in 505 publications. In Europe, drone delivery research is dominated by the UK, with 96 publications. Countries such as Italy, Germany, France and Spain also made significant contributions, recording 58, 52, 32 and 32 publications, respectively. Drone delivery research in North America is dominated by the USA, with 274 publications. Canada and Trinidad and Tobago are the other two countries with research output, having 60 and 1 publications, respectively, in drone delivery. Oceania, with 4 countries contributing to drone delivery research, has a moderate contribution with a total of 82 publications in the period 2015–2024. Australia is the leading contributor with 63 publications, followed by New Zealand, which contributed 9 publications. Fiji and Papua New Guinea had the least impact, with only 1 published article each. Regarding South America, seven countries were involved in drone research, resulting in a total of 42 publications. The leading countries are Brazil, Chile, and Argentina, with 21, 10, and 5 publications, respectively. Africa has the lowest research output in drone delivery, with 14 countries contributing to 45 publications. Egypt, with 7 publications, is the leading contributor in Africa, followed by Morocco, South Africa and Tunisia with 6 publications each.

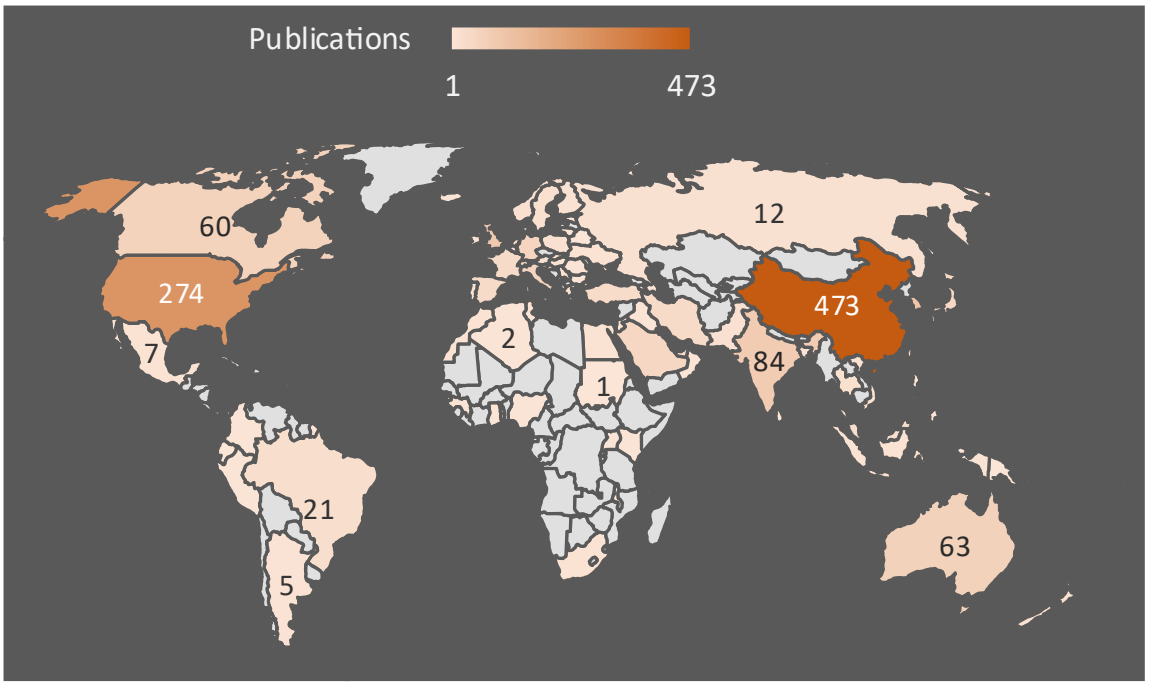

Figure 4A. *Distribution of countries contributing to drone delivery research: Publications.*

Figure 4B shows the citation rate for the 90 countries involved in drone delivery research. Asia is leading other continents with 21,560 citations. China is leading Asia, having accumulated 8,596 citations from 2015 to 2024. South Korea follows with 4,029 citations, while India and Qatar have 1,623 and 955 citations, respectively. North America came second with 13,314 citations, with the USA leading others, having obtained 11,264 citations, while Canada and Trinidad and Tobago accumulated 2,044 and 6 citations, respectively. European countries collectively garnered 11,731 citations, with the UK, Germany, Turkey and Italy having 2,020; 1,609; 1,336 and 1,230 citations, respectively. The moderate impact of Oceanic countries on drone delivery research is felt with 2,607 citations. Australia recorded 1,998 citations, while New Zealand earned 110 citations. Papua New Guinea and Fiji recorded 12 and 6 citations, respectively. Africa and South America make the least impact on drone delivery research, with citations of 865 and 743, respectively. The leading African countries are Egypt and Morocco, with 6 citations each, while Brazil and Chile lead in South America, with 17 and 10 citations, respectively.

Figure 4C presents the top 10 most productive countries in drone delivery research, showing three key bibliometric metrics: publications, citations and H-index. Considering the number of publications within the period under review, which spans from 2015 to 2024, China has the highest number of publications, followed by the USA. Other leading countries are South Korea, the UK and India, with Saudi Arabia having the fewest publications out of the 10 most productive countries. As for the citations, the USA has the highest number of citations, while China follows closely. Other countries such as South Korea, Canada and the UK have significantly fewer citations compared to the USA and China, while Italy and Saudi Arabia recorded the fewest citations. The H-index, which reflects the impact and quality of research output, shows that the USA has the highest H-index, followed by China. The H-index for both the USA and China indicate a considerable volume and influence of their research output. Although other countries such as Canada, Germany and Saudi Arabia contribute to drone delivery research, their lower H-index implies that their impacts are not wide.

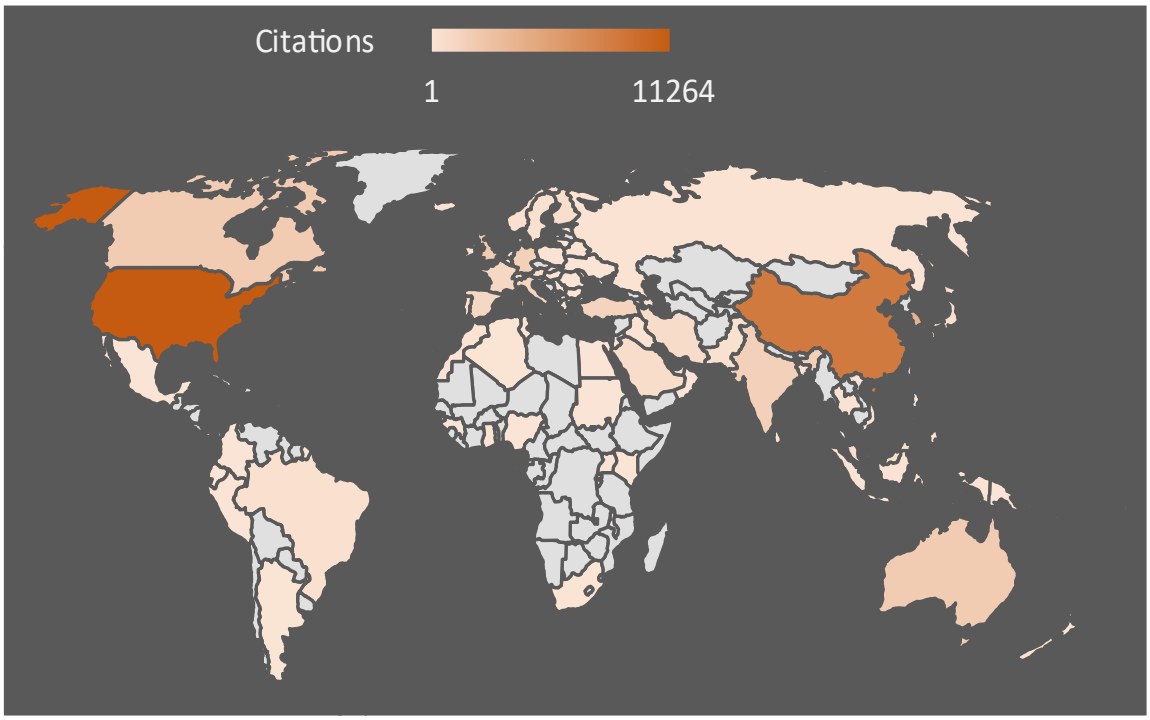

Figure 4B. *Distribution of countries contributing to drone delivery research: Citations.*

Considering its high publication output, citations and H-index, China is the global leader in drone delivery research. The USA comes next to China as a key player with a substantial impact on drone delivery research. South Korea, the UK, India and Australia also contribute to drone delivery research, but with less visibility and impact compared to China and the USA. The low citations and H-index values of Italy and Saudi Arabia might be due to their being new entrants in drone delivery research or a lack of influence in the domain. Drone delivery research is largely dominated by regions with high technological advances and strong infrastructure, including Asia, North America, Europe and Oceania. Notably, none of the African or South American countries are among the leading countries in drone delivery research. The absence of Africa and South America in the top 10 spots brings to the fore a shortage in technological investment, research infrastructure and regulatory framework necessary for advancing drone research.

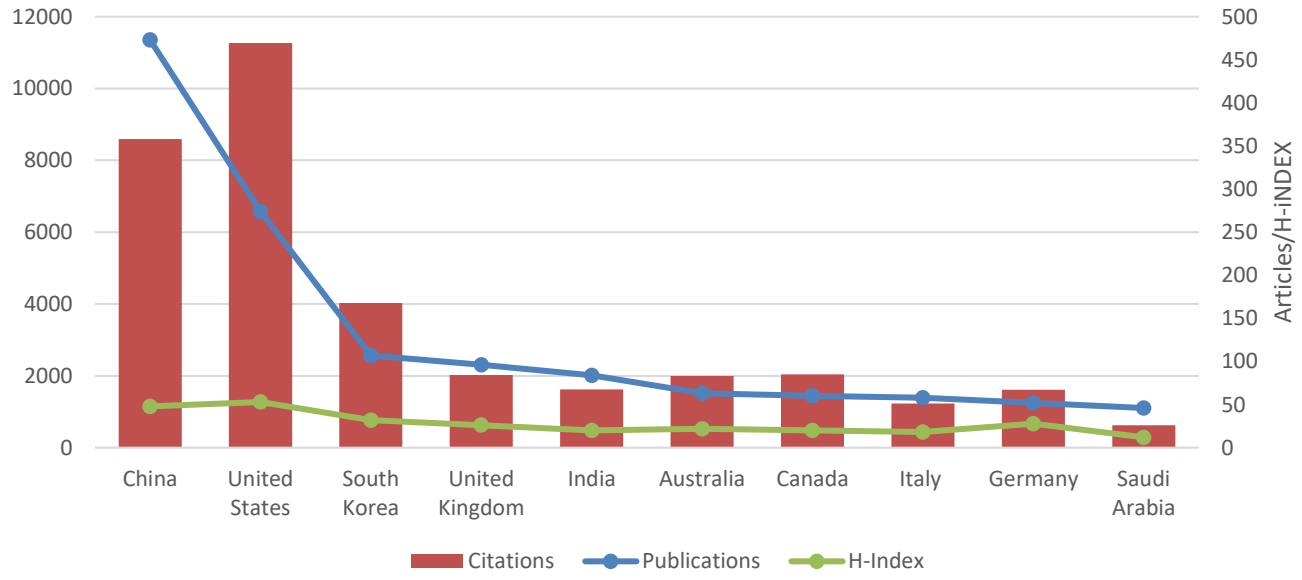

Figure 4C. *Citations, publications and H-index of countries.*

In Figure 5A, a co-authorship analysis of the countries is conducted using VOSviewer to discover the collaboration patterns among the countries, elucidating global scientific cooperation and knowledge sharing, obtained in VOSviewer by setting the minimum number of documents of a country and citations to 5 and 1 respectively. Countries that frequently collaborate are placed closer in the network and grouped in the same cluster.

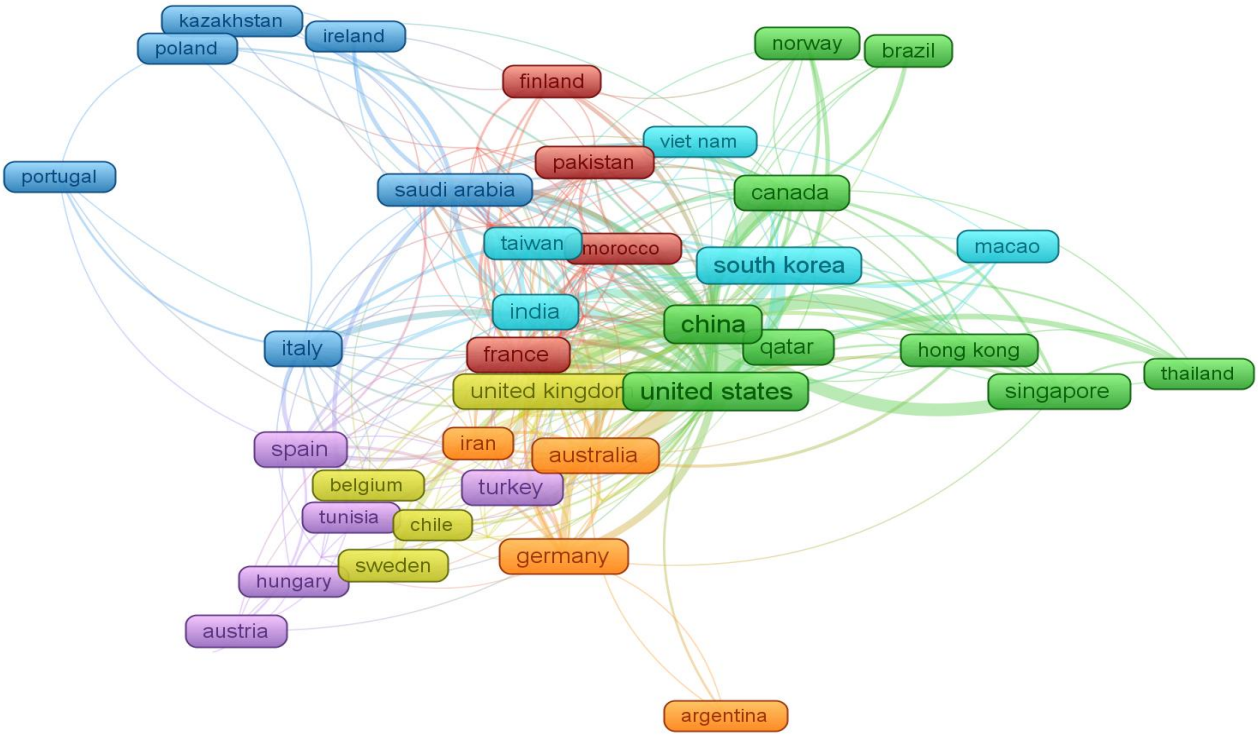

Figure 5A. *Network visualisation of co-authorship analysis of countries.*

Out of the 106 countries involved in drone delivery research collaboration, the 54 countries that met this threshold are grouped into 7 clusters, with different colours representing each cluster and with diverse total link strengths (TLS). TLS represents the sum of the link strength of a country with other countries based on the number of joint publications.

Cluster 1, represented with pink, has 11 countries that range between 9 and 44. In this cluster, France led with a TLS of 44, indicating its vibrancy and collaborative strength in drone delivery research. The United Arab Emirates (UAE) came second with a TLS of 34, while Morocco, with a TLS of 9, came last in Cluster 1. As for Cluster 2, represented with green, China led the pack with a TLS of 247 followed by the USA with a TLS of 177, while Brazil with a TLS of 8 came last. This implies that while China and the USA are key players with significant impact and collaboration in drone delivery research globally, China has more impact and collaboration than the USA. Cluster 3, represented with navy blue, consists of 9 countries. Saudi Arabia came first in this cluster with a TLS of 70, followed by Italy with a TLS of 24, while Greece has the lowest TLS of 1, signifying the least research collaboration in drone delivery research. The fourth cluster, denoted with yellow, consists of 8 countries with TLS from 113 to 7. The UK leads the cluster with a TLS of 133; coming in at a distant second is Denmark with a TLS of 31. Belgium has the lowest TLS of 7, meaning that it has the least research collaboration in the cluster. Cluster 5, denoted with the colour purple, is made up of 7 countries collaborating on drone delivery research. Spain is leading this cluster with a TLS of 28, followed by Turkey with a TLS of 21. Romania is the country with the least research collaboration, with a TLS of 1. Cluster 6, with a light blue colour, is made up of India, South Korea, Taiwan, Macao and Vietnam, with India being the leader of the cluster, having secured a TLS of 75, while South Korea has a TLS of 64. With a TLS of 8, Vietnam has the fewest research collaboration activities in this cluster. In Cluster 7, Australia and Germany are the dominant contributors to international research collaboration, as indicated by their high TLS values of 68 and 44. Iran shows moderate participation with a TLS of 16, while Argentina plays a minimal role with a TLS of 4.

These disparities highlight opportunities for fostering more balanced partnerships, particularly for countries with lower TLS, to enhance global research integration. Among the 54 countries engaged in drone delivery research

collaboration, China dominates with a remarkable TLS of 247, indicating extensive collaboration and impact. The USA follows with a TLS of 177, signifying significant but lesser engagement compared to China. Other notable contributors include the UK and India, with TLS values of 133 and 75, respectively. France also shows strong collaboration with a TLS of 44. However, countries such as Brazil, Morocco and Belgium have lower TLS values, ranging from 8 to 9, suggesting less extensive research collaboration in the field. The analysis highlights the disparities in international research partnerships, with some countries such as China and the USA leading the way, while others have opportunities to enhance their global research integration.

Figure 5B displays the visualisation of countries' bibliographic coupling, representing the degree to which countries are connected based on shared references in academic publications, with the time frame index (colour gradient) describing the evolution of the coupling over the time frame under review. The figure shows five threads represented by colours and time frames.

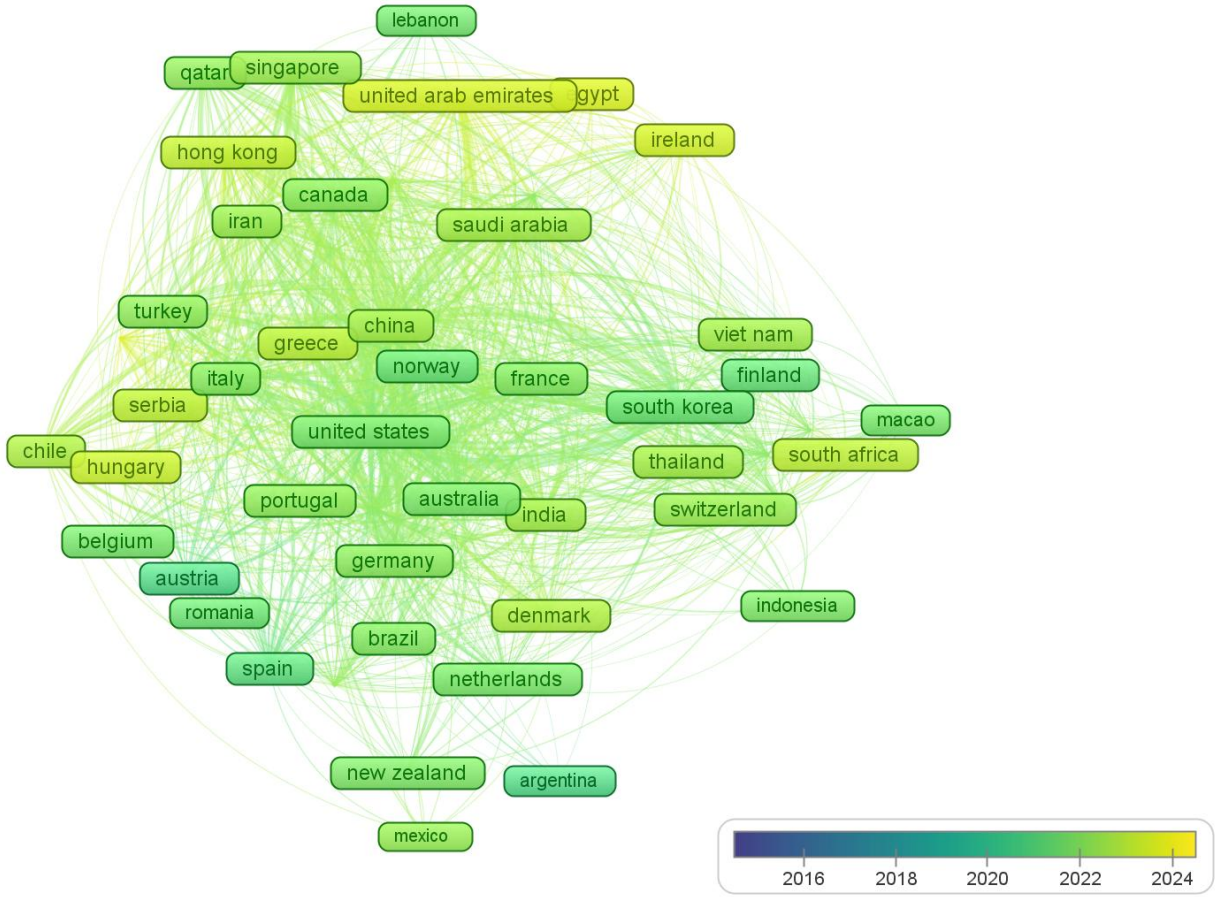

Figure 5B. *Visualisation of bibliographic coupling of countries.*

The three countries, Lebanon, Iran, and Macao constitute peripheral players in the period before 2016. This cluster is less central in the research network and exhibits weak ties with the main research hub. Iran led the cluster with a TLS of 20,814 followed by Macao 2,973, while Lebanon had the lowest TLS of 1,465. This group might be isolated due to less involvement in international collaborations or focusing more on internal rather than global collaborations. The dark green cluster in the visualization map, made up of Italy, Greece, Belgium, Romania, Spain, Austria, Denmark, Hungary, Serbia, Turkey, Argentina, Chile, New Zealand and Mexico, characterises countries with significant research collaborations in earlier time frames (before 2016) but then again less dominant in the more recent bibliometric network. In the past, these countries made significant contributions to drone delivery research networks, evidenced by their links to other countries, signifying strong integration into earlier international collaborations. Turkey led this cluster with a TLS of 17,519 followed by Chile with a TLS of 11,815, while Romania has the lowest TLS of 222.

The pattern of collaborations is mostly aligned geographically or culturally, as evident with countries such as Italy, Greece, Spain, Austria and Hungary, belonging to the European Union, exhibiting stronger collaborations. Also visible are the Latin American connections between Argentina, Chile and Mexico. Their coupling may focus more on regional networks rather than extensive global collaborations. The green cluster 2016–2018 represents the established collaborators. In this cluster are countries that include Australia, Brazil, Germany, France, Norway, Switzerland, the Netherlands, Finland, Portugal and the USA, spanning across multiple continents. These countries are collaboration leaders serving as a research hub that connects peripheral players to the main research stream due to their well-funded and leading large international research consortia, enabling widespread bibliographic coupling. The USA, with a TLS of 123,563, is the most influential country in the cluster with extensive collaboration with both evolving (e.g., China, India) and established countries (e.g., Germany, France). Germany and France serve as a significant European research hub connecting to global research partners. At the same time, Australia and Brazil serve as a link between Oceania and South America within the global research community. This cluster typifies stability and leadership in the global drone delivery research ecosystem.

The light-green cluster denotes the core active countries in drone research collaboration. These countries, including Saudi Arabia, South Korea, Hong Kong, China, India, Canada, Thailand and South Africa, serve as bridges between emerging contributors (yellow) and established hubs (dark green). The geographical diversity of this cluster, spread across different continents (Africa, Asia and North America), is indicative of their significant contributions to global collaborations in drone research. Most of the countries in this cluster, especially China, India, Saudi Arabia and South Korea, have witnessed rapid growth in research output during this period as a result of increased funding that enables vigorous collaborations with both traditional research hubs (e.g., the USA and Germany) and emerging countries (e.g., Vietnam and Qatar). China is the most prolific and prominent collaborator in this cluster with a TLS of 143,399 as attested to by its massive bibliographic coupling. South Korea and India follow with TLS of 37,842 and 32,552, respectively, while Thailand and South Africa show less significance in the cluster with TLS of 5,550 and 2,857, respectively. This cluster plays a strategic role in connecting global research networks by providing a balance between established research powers and newer contributors, making them indispensable in driving global scientific progress.

Lastly, the yellowish cluster represents countries with the more recent bibliographic coupling activity between 2022 and 2024. As shown in the visualisation map, these countries include Ireland, Vietnam, the UAE, Qatar, Egypt and Singapore. These are new entrants in drone delivery research with little or no prior research activities in drone delivery, but are undergoing a surge in research activity and international collaborations in recent years, backed by heavy investment in R&D in countries such as the UAE, Qatar and Egypt. Driven by funded initiatives, global challenges (e.g., climate change and pandemics) or knowledge transfer programmes, this cluster collaborates with established hubs (such as the USA, Germany and China), using those partnerships to boost its research visibility. In this cluster, Singapore leads the pack with a TLS of 17,691 followed by the UAE with a TLS of 15,202, while Egypt has the lowest TLS of 2,270. The yellowish cluster represents a vibrant collection of up-and-coming research countries rapidly influencing the global academic scene by using new collaborations and investments to increase their bibliometric network influence. The visualisation highlights the shifting dynamics of global research, with emerging countries in Asia and the Middle East becoming increasingly central to academic networks. Despite this growth, traditional Western research centres continue to exert enduring influence.

4.2 Journals as main outlets for drone delivery publications and their relative impact

4.2.1 Most sought-after journals

Table 2 provides a comprehensive overview of the top Scopus-indexed journals publishing research articles on drone delivery research between 2015 and 2024. Based on publication output, Drones led the other journals with a total of 83 articles published between 2015 and 2024. This reflects its dominance as a first choice among drone delivery researchers. This is distantly followed by the IEEE Transactions on Intelligent Transport Systems, Sustainability and IEEE Access Journals with 44, 37 and 36 publications, respectively, indicative of significant contributions to drone delivery research. Other journals such as IEEE Transactions on Vehicular Technology, Remote Sensing and IEEE Internet of Things made a moderate impact with the publications of 33, 32 and 30 articles respectively, while the remaining journals are less influential, having published fewer than 30 articles each.

Table 2. *Top 10 most publishing journals.*

Sources	Publications	H-index	Citations	Publisher
Drones	83	15	805	MDPI
IEEE Transactions on Intelligent Transportation Systems	44	18	732	IEEE
Sustainability (Switzerland)	37	13	550	MDPI
IEEE Access	36	13	617	IEEE
IEEE Transactions on Vehicular Technology	33	15	807	IEEE
Remote Sensing	32	11	417	MDPI
IEEE Internet of Things Journal	30	12	673	IEEE
Transportation Research Part C: Emerging Technologies	29	16	2287	Elsevier
Applied Sciences (Switzerland)	26	8	205	MDPI
Sensors	20	7	576	Elsevier

However, in terms of impact (H-index), IEEE Transactions on Intelligent Transportation Systems is ahead of others with an H-index of 18, followed by Transportation Research Part C: Emerging Technology with an H-index of 16. These two constitute the highest-ranking journals on drone delivery research. Drones and IEEE Transactions on Vehicular Technology with an H-index of 15 each imply their high regard for influential research into drone delivery. Other journals, such as Sustainability and IEEE Access made a moderate impact on drone delivery research with an H-index of 13 each, while the rest of the journals have less impact with an H-index that ranges between 12 and 7. Considering the number of citations, Transportation Research Part C: Emerging Technology is the most cited journal, with a citation count of 2,287. This journal is likely to be a major citation hub for research into intelligent transport systems that incorporate drones. Journals such as IEEE Transactions on Vehicular Technology and Drones also accumulate substantial citation counts of 807 and 805, respectively, highlighting their influence in the drone delivery research domain. The rest of the journals have citation counts that range between 732 and 205, indicating low impact in the domain.

All the top 10 journals were published by three dominant publishers: MDPI, IEEE and Elsevier. MDPI with four journals (Drones, Sustainability, Remote Sensing and Applied Sciences) in the top 10, emerges as a leading and significant publisher in the drone delivery research domain. This can be attributed to the publisher's multi-disciplinary focus and open-access policy. IEEE as a forerunner professional organisation within engineering and technology, has four of its journals (IEEE Transactions on Intelligent Transportation Systems, IEEE Transactions on Vehicular Technology, IEEE Access and IEEE Internet of Things) as publishers on drone delivery research, reflecting its dominance and relevance in drone research. However, Elsevier with only two journals (Transportation Research Part C: Emerging Technology and Sensors) in the top 10, has demonstrated its influence and contributions in drone delivery research with one of its two journals having the highest citation counts. The bibliometric analysis of the top journals in drone research between 2015 and 2024 exposes high-impact journals such as Drones and IEEE Transactions on Intelligent Transportation System, while Transportation Research Part C led with the highest citations. MDPI led two other publishers, IEEE and Elsevier, to emerge as the top publishers in the drone delivery research domain. The growing number of publications in these journals manifests a rising interest in drone research.

4.3 Authors and institutions as most influential contributors to drone delivery research and their collaboration

4.3.1 Key authors

Table 3 presents the top 10 most prolific authors in drone delivery research from 2015 to 2024, illustrating trends in productivity (publications), impact (citations) and influence (H-index) among the 10 top authors. Of the top 10 most prolific authors in the drone delivery research domain, Hwang and Choe (2019) stand out as the most influential authors with the highest number of 18 publications and a remarkable 1,415 citations, coupled with an H-index of 17. This implies that the authors are prolific writers with a consistent impact whose work is frequently referenced and highly significant in the drone delivery research domain. This is followed by Lan et al. (2021) with 15 publications that have garnered a large number of 465 citations and an impressive H-index of 9. Although Lan et al. (2021) have

been productive authors based on the number of publications, the authors' impact is moderate compared to Hwang and Choe (2019). Kim and Hwang (2020) with 10 publications, have gathered an impressive 785 citations and an H-index of 10. Compared to Lan et al. (2021), Kim and Hwang (2020) have fewer publications; however, Kim and Hwang (2020) have more citations and a higher H-index, implying the authors' high influence and impact in the drone delivery domain. The high citations might be indicative of the specialised or pioneering nature of the authors' work with significant contributions. Peng et al. (2015) with 10 publications, 365 citations and an H-index of 8, seem to be rising authors with moderate productivity and a fair amount of influence.

Table 3. *Top 10 most cited authors.*

Author	Publication	Citation	H-index
Hwang and Choe (2019)	18	1415	17
Lan et al. (2021)	15	465	9
Kim and Hwang (2020)	10	785	10
Peng et al. (2015)	10	365	8
H. Huang et al. (2020)	9	291	8
G. Wang et al. (2023)	8	205	6
Wu et al. (2022)	8	195	6
H. Zhang et al. (2023)	8	39	3
C. Huang et al. (2022)	7	222	6
Song et al. (2021)	7	159	6

Figure 6A. *Network visualisation: co-authorship analysis of authors.*

H. Huang et al. (2020), with 9 publications that have attracted 291 citations, yielding an H-index of 8, portray authors with fewer publications and moderate citations but with the same level of impact as Peng et al. (2015). Although G. Wang et al. (2023), Wu et al. (2022) and H. Zhang et al. (2023) have a total of 8 publications each, their citations and H-indices differ. However, both G. Wang et al. (2023) and Wu et al. (2022) have 205 and 195 citations respectively,

while H. Zhang et al. (2023) have a very low citation rate of 39. Regarding the H-index, both G. Wang et al. (2023) and Wu et al. (2022) have the same H-index of 6, while H. Zhang et al. (2023) have the lowest H-index of 3. This implies that while the 3 teams of authors have been active with 8 publications, H. Zhang et al. (2023) have less visibility and impact in the drone delivery domain. As for C. Huang et al. (2022) and B. Li et al. (2023), both teams have the same number of publications and an H-index of 7 and 6 respectively. Although C. Huang et al. (2022) are more active with 222 citations as against 159 by B. Li et al. (2023), both teams made steady contributions and have a similar impact on the field. In summary, Table 3 shows a blend of prolific, high-impact authors and constant contributors in drone delivery research between 2015 and 2024, with Hwang and Choe (2019) being the most prolific and influential authors. The co-authorship analysis below (Figure 6A) is obtained from VOSviewer by setting the minimum number of documents and citations of the authors to 5 and 2 respectively.

Out of the 5,456 authors, only 29 met this threshold. The VOSviewer map of co-authorship analysis exposes collaborative patterns among 29 authors with citation ranges of 15–377, forming 17 diverse clusters, each represented by different colours, 20 links and a TLS of 104. Cluster 1 in red comprises 5 authors with Peng et al. (2015) leading this cluster with 12 publications, 377 citations, 4 links and a TLS of 24, representing a significant contribution to drone delivery research collaborations. The authors X.-B. Li et al. (2018) and Q. Chen et al. (2020) each have 4 links and TLS of 19 and 17 respectively in Cluster 1, denoting significant collaborations and impact in drone delivery research. The rest of the authors, Song et al. (2021) and Z.-H. Chen et al. (2024), each have 3 links with TLS of 15 and 7 respectively. As for Clusters 2, 3 and 4 in green, blue and yellow, each consists of 3 authors with 2 links correspondingly. Cluster 2 is led by H. Huang and Savkin (2021) with a TLS of 16, while Clusters 3 and 4 are led by Lan et al. (2021) and H. Zhang et al. (2023) with TLS of 13 and 9 respectively. Clusters 5 and 6 in purple and light blue each have 2 authors with 1 link and TLS of 10 and 4 respectively. Although Clusters 5 and 6 have 1 link only, the high TLS of 10 and 4 respectively indicate a high level of research collaborations within the cluster. The rest of the clusters (7–17), consist of 11 authors without collaboration, resulting in 0 links and TLS of 0. Nevertheless, there exist some authors in these clusters such as Bera et al. (2020), Moshref-Javadi et al. (2020) and Wan et al. (2020) with over 300 citations, which is indicative of their positive impact on the domain. Nonetheless, these high citations of the authors do not translate into global collaboration in the long run. Likewise, Figure 6B shows the authors' co-citation analysis, showing their scholarly influence and thematic connections. The co-citation analysis of cited authors shown in Figure 6B is obtained by setting the minimum number of authors' citations to 60.

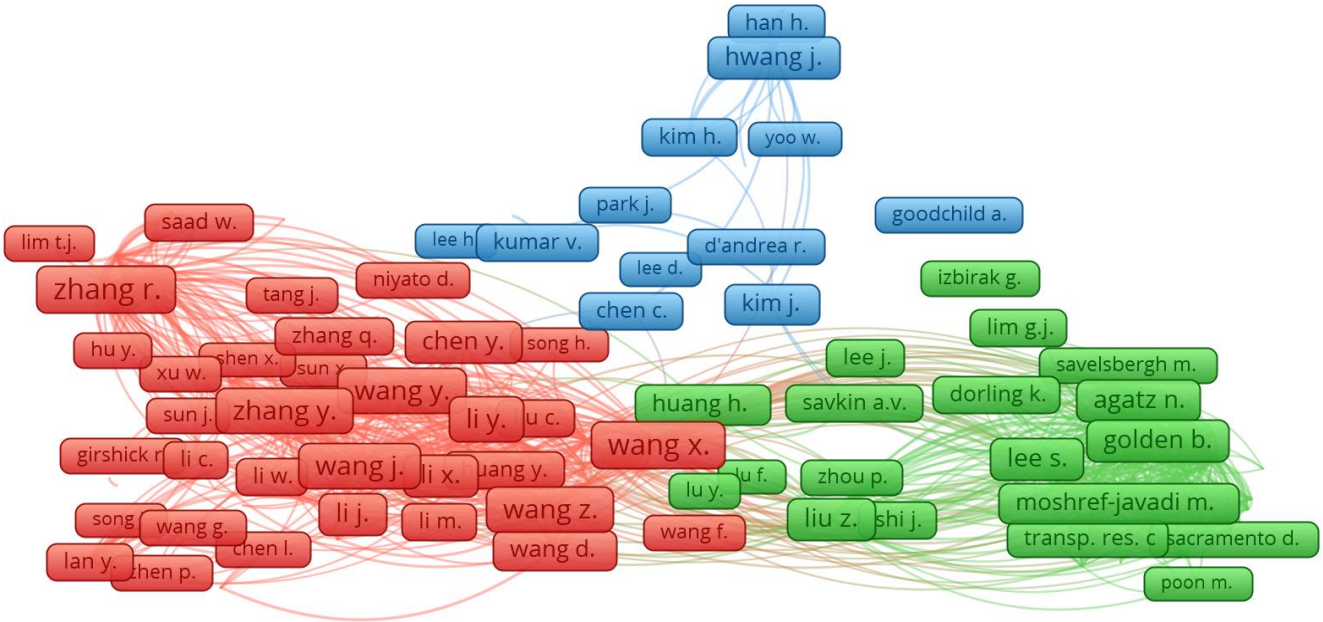

Figure 6B. *Co-citation analysis of cited authors.*

Out of the 78,027 authors involved, 308 met this threshold. The network visualisation of the co-citation analysis of the cited authors, as obtained from VOSviewer, is classified into three clusters: 308 authors, 42,130 links and a TLS of 952,115. Cluster 1 in red has 163, Cluster 2 in green has 108 and Cluster 3 in blue has 37 authors. The clustering is

done based on authors whose work is cited together frequently. This clustering provides an understanding of influential authors and the main research themes in drone delivery.

Cluster 1 has the largest number of authors and is also the most densely connected cluster with authors such as X. Wang et al. (2019), Xu et al. (2018) and Y. Li et al. (2020) dominating with significant research co-authorship resulting in high TLS of 27,402; 23,929; and 21,928 respectively. These authors are likely prominent in a specific research domain, possibly related to engineering, computer science or artificial intelligence. As for Cluster 2, authors such as Liu and Gao (2024), Poikonen and Golden (2020) and Lee et al. (2022) dominate this cluster with TLS of 24,215; 23,162; and 22,847 respectively. Their high TLS indicates strong and influential contributions to and collaborations in drone delivery research, focusing on logistics, transport and operation management. Cluster 3 is the least populated with 37 authors but with strong interconnections. The leading authors of this cluster include Hwang and Choe (2019), (Park et al. (2023) and C.-L. Chen et al. (2024) with TLS of 11,677; 8,788; and 8,093 respectively. The focus of this cluster includes logistics, communications and drone delivery. The collaborative patterns among the authors show the extent of collaboration and knowledge sharing among the drone delivery research community, as the co-authorship study discovered. Authors with high TLS are key influencers and bridge builders across academic networks. These partnerships might have produced more thorough investigations, creative methods and multidisciplinary research that have benefited the expansion and advancement of the drone delivery research community. The co-citation analysis of the cited top 10 authors shown in Figure 6C is a subset of Figure 6B obtained by setting the minimum number of the authors' citations to 380.

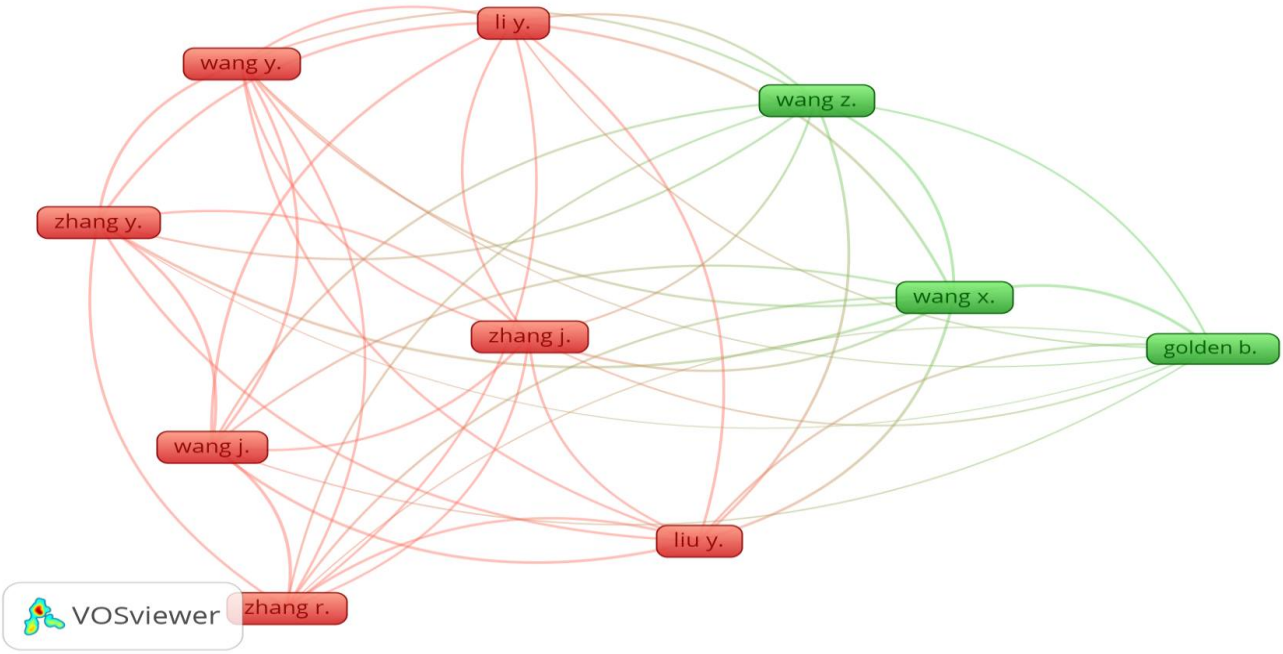

Figure 6C. *Co-citation analysis of cited top 10 authors.*

The network visualisation of the co-citation analysis of the cited authors, as generated from VOSviewer, is classified into two clusters: red and green, with 10 authors, 45 links and TLS of 12,609 in total. Cluster 1 in red has 7 prominent authors, all with TLS above 2,300. Authors with the highest TLS in this cluster are Liu and Gao (2024); J. Wang et al. (2023); Y. Zhang et al. (2024), with TLS of 2,895, 2,890 and 2,080, respectively, representing strong collaborations with several authors in drone delivery research. Other prominent authors, though with less TLS compared to the cluster leaders, include Y. Li et al. (2020), Y. Wang et al. (2022), Xu et al. (2018) and J. Zhang and Li (2023),with TLS that ranges between 2,623 to 2,360. The high interconnectivity implies that authors in this cluster are shaping the core technical and logistical frameworks for drone delivery. Although the major contributions of this cluster include solving optimization problems, AI-driven logistics and operational efficiency, their research output influences and contributes to drone regulations, risk assessment and airspace management strategies. Although Cluster 2 is less densely connected with only 3 authors, it however, boasts of influential authors: X. Wang et al. (2019), Poikonen and Golden (2020) and Peng et al. (2015) with TLS of 3,056, 2,273 and 1,504, respectively. The presence of the author with

the highest TLS (3,056) in the green cluster is indicative of the fact that, despite its low density, the cluster makes a substantial impact and contribution to drone delivery research.

4.4 Most cited articles shaping intellectual and practical foundations of drone delivery research

4.4.1 Most cited articles

The top 10 most cited articles in the research domain of drone delivery for the period 2015–2024 are displayed in Table 4, ordered by the number of citations received.

Table 4. *Top 10 most cited articles.*

Title	Author	Citations	Avg. annual citations
The flying sidekick traveling salesman problem: Optimization of drone-assisted parcel delivery	Murray & Chu (2015)	1024	93.1
Vehicle routing problems for drone delivery	Dorling et al. (2016)	832	92.4
UAV-enabled intelligent transport systems for the smart city: Applications and challenges	Menouar et al. (2017)	719	79.9
UAV-enabled wireless power transfer: Trajectory design and energy optimization	Xu et al. (2018)	460	57.5
Energy use and life cycle greenhouse gas emissions of drones for commercial package delivery	Stolaroff et al. (2018)	342	42.
The multiple flying sidekicks traveling salesman problem: Parcel delivery with multiple drones	Murray & Raj (2020)	299	49.8
Wireless communication using unmanned aerial vehicles (UAVs): Optimal transport theory for hover time optimization	Mozaffari et al. (2017)	294	32.7
Coordinated logistics with a truck and a drone	Carlsson & Song (2018)	271	33.9
Delivery by drone: An evaluation of unmanned aerial vehicle technology in reducing CO_2 emissions in the delivery service industry	Goodchild & Toy (2018)	266	33.2
Optimization of a truck-drone in tandem delivery network using *k*-means and genetic algorithm	Mourelo Ferrandez et al. (2016)	259	25.9

The article titled "The flying sidekick traveling salesman problem: Optimization of drone-assisted parcel delivery", authored by Murray and Chu (2015), is the most-cited article in the drone delivery research domain with 1,024 citations and an average annual citations (AAC) rate of 93.1. Published in 2015, the article laid the foundation for combining drones with trucks to optimise parcel delivery by presenting two heuristic models. The next is the article by Dorling et al. (2016), which was published in 2016 with 832 citations and an AAC of 94.4. The authors proposed simulated annealing and mathematical models for route planning to address issues of battery and payload for delivery drones. Integrating drone delivery into existing urban infrastructures, such as intelligent transport systems and smart cities, was the focus of the article by Menouar et al. (2017). With 719 citations and an AAC of 79.9, the work identified uses for drones in smart cities, such as traffic management and emergency response, while identifying regulatory, operational and technical issues as hindrances to drone integration in smart cities. Rather than product deliveries, the works of Xu et al. (2018) and Mozaffari et al. (2017) centred on the innovative application of drones to deliver power and data services respectively.

Their work laid the foundation for novel applications of drones for intangible product delivery, garnering 460 and 294 citations and an AAC of 57.5 and 37.2, respectively. Concerned about greenhouse gas emissions from conventional truck delivery, both Stolaroff et al. (2018) and Goodchild & Toy (2018) proposed the adoption of drones in delivery due to their low CO_2 imprints. Their research findings reveal that drones use less energy per package/km relative to truck delivery, resulting in lower environmental impacts, with each article gaining 266 and 342 citations and AAC of 42.8 and 33.2, respectively. Following the influential work of Murray & Chu (2015) on drone-truck delivery, several other influential articles such as Mourelo Ferrandez et al. (2016), Carlsson & Song (2018) and

Murray & Raj (2020), focusing on drone-truck delivery, were published between 2016 and 2020, having citation counts of 259, 271 and 299 and an AAC of 25.9, 33.9 and 49.8 respectively. The focus of the most cited articles on drone delivery between 2015 and 2024 ranges from delivery optimisation and environmental impact to energy efficiency and integration with existing systems, such as smart cities. The authors brought to the fore the advantages of drone delivery, such as energy saving, fast delivery and lower CO_2 emissions. Challenges slowing the broad adoption of drone delivery including battery life, infrastructure and regulations were also identified.

5 EMERGING TRENDS AND THEMATIC AREAS THAT CAN BE IDENTIFIED THROUGH KEYWORD CO-OCCURRENCE AND THEMATIC MAPPING

5.1 Keywords and co-occurrence analysis

Figure 7 shows the co-occurrence analysis of the author keywords as obtained using VOSviewer. Co-occurrence analysis of author keywords enables the analysis of how author keywords frequently appear across academic publications. Patterns in scholarly bibliometric data, exposing common themes and relationships between different research areas based on the frequency of author keywords, were discovered using VOSviewer (Ding & Yang, 2022). Of the 4,171 keywords used by authors in drone delivery research, 141 with at least 5 appearance frequencies across all the documents were identified.

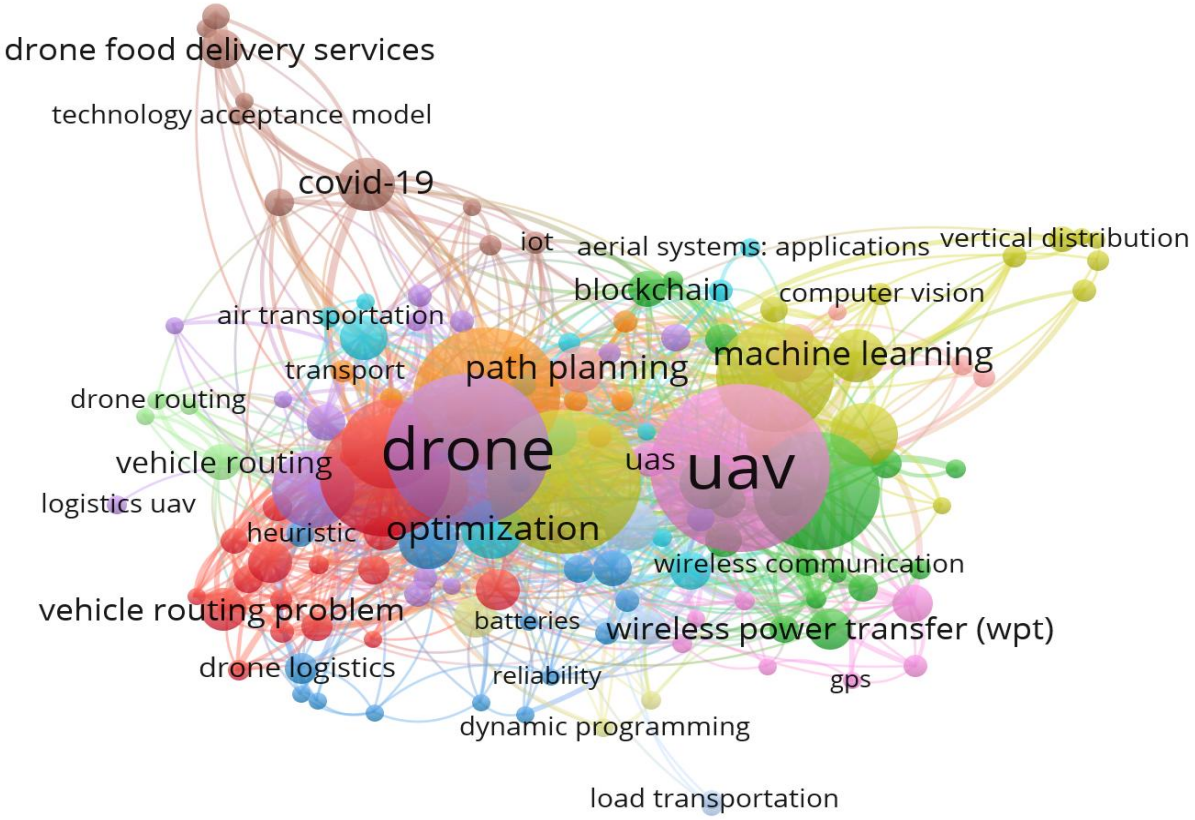

Figure 7. *Co-occurrence analysis of author keywords.*

The bibliographic data, along with the keyword co-occurrence diagram, reveal 13 clusters represented with different colours. Cluster 1 with a red colour has 18 keywords, which is the highest number of all the 13 clusters. Keywords with the highest occurrence in Cluster 1 include “drone delivery”, “logistics” and “vehicle routing problem” with 88, 56 and 20 occurrences respectively. The focus of this cluster is integration of drone delivery into logistics operations, with an emphasis on optimization of delivery routes and the overall supply chain. The high occurrence of these keywords signifies their significance in the authors' research and development efforts to promote the efficiency and effectiveness of drone delivery systems within the broader logistics context, leading to more streamlined and cost-effective delivery processes.

Cluster 2 in green and Cluster 3 in light blue contain 17 keywords each. In Cluster 2, "unmanned aerial vehicle (UAV)" is the leading keyword with 86 occurrences, hinting at the fundamental role of UAV technology. Research into energy-efficient drone operations is reflected through mentions of "wireless power transfer" (25 times). "Blockchain" occurs 15 times, indicating an exploration of secure and transparent transaction systems for delivery by drones. "Internet of things" and its abbreviation "IoT" are both important terms in this context, with 14 and 11 occurrences, respectively, indicating the integration of drones with smart networks. As for Cluster 3, "routing" is the most frequently occurring keyword in this cluster, with 28 mentions, indicating the focus on navigation and path planning. Next are "delivery" and "energy efficiency" with 15 occurrences each, indicative of the real-world application of drones in logistics and delivery and efforts to improve drone battery efficiency. "Drone logistics" was mentioned 12 times, reinforcing the importance of integrating drones in supply chains, while "package delivery" was mentioned 10 times, reiterating the adoption of drones for delivery purposes.

The golden colour denotes Cluster 4, which consists of 15 keywords dominated by "unmanned aerial vehicle (UAV)" and its variation "unmanned aerial vehicle" with 113 and 77 occurrences, representing its massive use within drone technology. This cluster is dominated by AI and ML keywords such as "transfer learning" (34 occurrences), "machine learning" (26 occurrences) and "deep learning" (19 occurrences), manifesting the increased incorporation of AI-driven solutions and ML techniques to improve drone operations. Other noteworthy keywords are "convolutional neural networks" (5 occurrences) and "object detection" (26 occurrences).

Cluster 5 is coloured purple and consists of approximately 15 keywords. The most frequent keywords in this cluster are "drone" (124 occurrences), "last-mile delivery" (45 occurrences), "e-commerce" (15 occurrences), "photogrammetry" (10 occurrences) and "same-day delivery" (5 occurrences). This cluster revolves around the use of drones in last-mile delivery units, primarily for e-commerce purposes. The high frequency of two keywords "drone" and "last-mile delivery" indicates a pronounced interest focused on upgrading the last segment of the delivery process. Cluster 6 is a light blue cluster that covers 12 keywords. The most frequently occurring keywords in this cluster are "optimization" (31 occurrences), "urban mobility" (21 occurrences), "reinforcement learning" (17 occurrences) and autonomous aerial vehicles" (16 occurrences). This cluster is developed based on autonomous aerial vehicles and their optimization with high-level algorithms such as reinforcement learning. The high rate with which both optimization and reinforcement learning are mentioned seems to indicate considerable interest in improving the autonomy and efficiency of delivery processes by way of drones. Cluster 7 in brown consists of a total of 11 keywords, in which "drones" has the highest occurrences of 105, the highest of all the clusters. Following this is "parcel delivery" which received 29 occurrences, while "city logistics" and "urban logistics" received 9 and 8. Thus, this cluster signifies the practical use of drones for parcel delivery in urban areas. The higher frequency of the keywords "drones", "urban logistics" and "parcel delivery" suggests that there is a heightened focus on improving the efficiency and reliability of delivery operations in urban areas.

The analysis of the light-brown Cluster 8 reveals an association of 10 keywords. The most central keywords within the cluster defining scope are "COVID-19" with 26 mentions, "drone food delivery service" with 17 mentions and "supply chain" with 7 mentions. The focus of this cluster is the effect of COVID-19 on drone and food delivery services. The high frequency of the terms "COVID-19" and "drone food delivery service" implies that there is a focus on the application of drones in food deliveries during the pandemic. The use of the keyword "supply chain" shows that this cluster looks at the implications of drone delivery on supply chains and people's willingness to accept such technology concerning public health emergencies.

In light green, Cluster 9 consists of 9 keywords. The keywords with the highest rate of appearance in this cluster are "UAV" with 143 occurrences, "remote sensing" with 16 occurrences and "GIS" with 8 occurrences. This cluster is centred around UAVs and their applications in remote sensing. The high frequency of "UAV" and "remote sensing" suggests that considerable interest is directed towards using UAVs in mapping and location-based services. This is likely to have a positive impact on drone delivery as it will enhance the planning and navigation of delivery routes, especially in rural and remote areas where conventional mapping data are sparse. Represented by green-yellow, Cluster 10 has a total of 6 keywords with "path planning" and "unmanned aerial vehicles (UAVs)" leading with 22 and 21 occurrences respectively. Following these is "artificial intelligence" with 10 occurrences. Artificial intelligence and optimization algorithms overall contribute to successful delivery operations. This cluster studies the combination of AI and path-planning algorithms.

Cluster 11 in light green and Cluster 12 in light blue consist of 4 keywords each. The top three most frequent keywords in Cluster 11 are “vehicle routing” (15 times), “drone routing” (6 times) and “heuristic algorithm” (5 times). This cluster is concerned with route optimization for drones and vehicles using heuristic algorithms. As for Cluster 12, the most frequently mentioned keywords in this cluster are “UAVs” with 24 mentions, “energy consumption” with 14 mentions and “quadrotor” with 6 mentions. This cluster emphasizes enhancing the energy efficiency of UAVs, especially quadrotors. Lastly, Cluster 13 in yellow-orange contains 3 keywords. The most mentioned keyword in this cluster is “transport” with 18 mentions, while “dynamic programming” and “energy optimization” have 6 mentions each. This cluster centres on applying dynamic programming and energy optimization techniques to improve drone transport systems.

Conclusively, it becomes clear that drone delivery is a complex field with various technological and operational dimensions being investigated. Clusters featuring high-frequency keywords such as “drone delivery”, “logistics”, “UAV” and “routing” underscore the necessity of optimizing drone delivery systems through advanced technologies and algorithms. These clusters typically focus on enhancing efficiency, reliability and integration into existing supply chains. Conversely, clusters with low-frequency keywords such as “adaptive large neighbourhood search”, “ant colony optimization” and “artificial intelligence” indicate that while these technologies are under exploration, they have not yet gained widespread adoption or study in the realm of drone delivery. These clusters may denote emerging research areas that could significantly affect the future of drone delivery.

The top 10 author keywords based on the highest frequency of occurrence are presented in Table 5. Among the listed keywords, certain terms emerge as particularly significant due to their high occurrences. Notably, “UAV” stands out with the highest number of occurrences (142), followed by keywords such as “drone” with 124 occurrences; “unmanned aerial vehicle” 113 and “drones” 107, which demonstrate substantial relevance and frequency in the literature.

Table 5. *Top 10 author keywords.*

Author keywords	Frequency
UAV	143
Drone	124
Unmanned aerial vehicle	113
Drones	105
Drone delivery	88
Unmanned aerial vehicle (UAV)	86
Unmanned aerial vehicles	77
Logistics	56
Last-mile delivery	45
Transfer learning	34

5.2 Keyword analysis

Figure 8A displays the word cloud obtained in R using the Biblioshiny package, which shows a total of 141 keywords with at least 5 occurrences used by authors in drone delivery research. The font size is directly proportional to the frequency of occurrence of each keyword, indicating their significance in drone delivery research. This visualization underscores the major themes shaping drone delivery research, ranging from “UAV”, “drone” and “unmanned aerial vehicle” with over 100 occurrences, to “routing optimization”, “truck-drone delivery” and “UAV logistics” with 5 occurrences.

In drone delivery research, author keywords with the highest occurrences include "UAV" (143), "drone" (124) and "unmanned aerial vehicle" (113). Although these 3 keywords refer to the same concept, this reflects researchers’ choice of using different terminologies interchangeably. Likewise, the differences in "UAVs" (77) and "UAV" (87) indicate varying nomenclature approaches across researchers. Underpinning the increasing attention to UAVs for delivery is the high number of “drone delivery" (88). A significant portion of drone research focuses on logistics and delivery optimization. The presence of keywords such as "logistics" (56), "last-mile delivery" (45), "parcel delivery"

(29), "routing" (29) and "path planning" (22) underpins their importance in drones for urban delivery and supply chain management. It also affirms concerted efforts to attain efficient navigation essential for promoting optimized flight paths and obstacle avoidance.

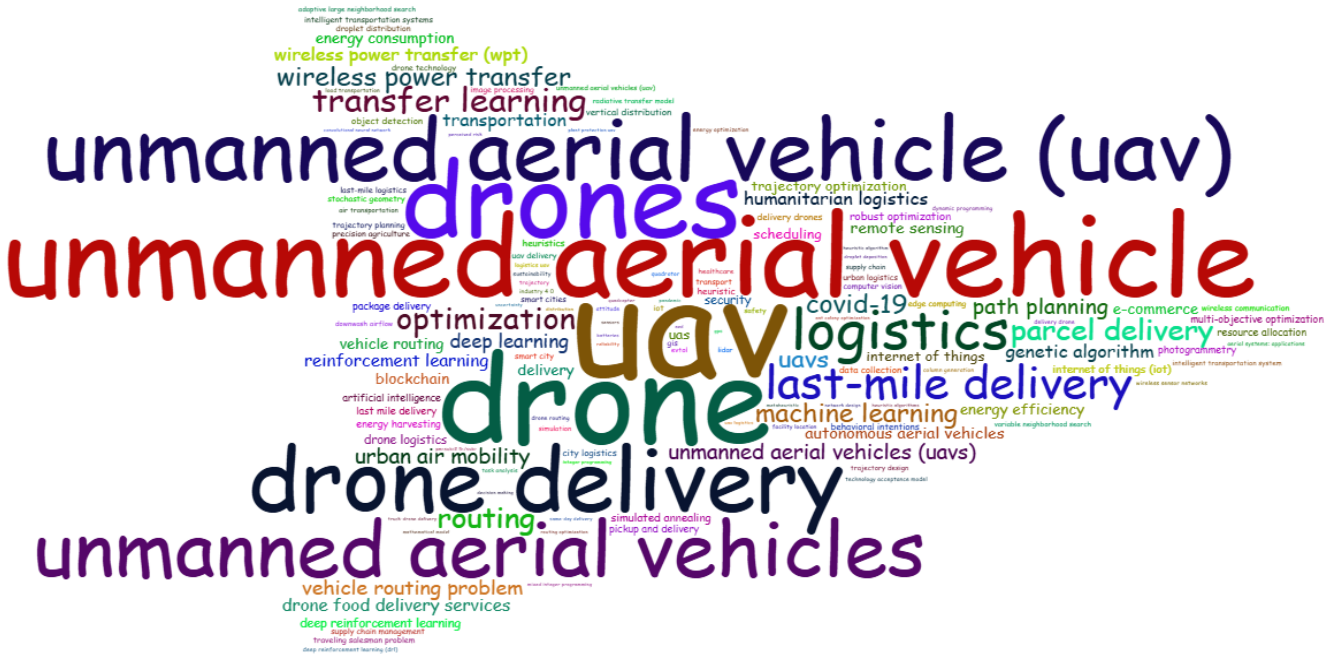

Figure 8A. *Word cloud of author keywords.*

Unending efforts to improve UAV performance through energy management, scheduling and optimization of delivery routes motivate the integration of artificial intelligence and machine learning in UAVs, as manifested with keywords such as "transfer learning" (34), "optimization" (31) and “machine learning" (26).

Additionally, the appearance of the keyword "wireless power transfer" (26 occurrences) is a pointer to research efforts towards solving battery limitation issues of drones by enabling remote energy charging methods to extend drone flight duration. The outburst of "COVID-19" (26) reflects spikes in drone applications during the pandemic as contactless delivery solutions became critical in transporting medical supplies and consumer goods while minimizing human interaction. The integration of UAVs into city-wide transport networks will soon become a reality with the emergence of "urban air mobility" (21), indicating rising interest in paving the way for autonomous aerial taxis. Analysis of the author keywords reveals swift advancement in drone delivery research, exemplified by increasing attention to logistics, AI-driven decision-making, energy-efficient flight operations and sustainable urban air mobility. The emergence of COVID-19 further strengthens the adoption of UAVs in logistics delivery.

Figure 8B. *Word cloud of top recurring keywords.*

Aside from the author keywords, another keyword analysis is the recurring keywords. Recurring keywords are sets of keywords or phrases that appear frequently across the titles, abstracts and keywords of academic publication datasets obtained through keyword co-occurrence analysis in R Biblioshiny, as displayed in Figure 8B.

On closer examination of Figure 8B, it is apparent that unmanned aerial vehicles (UAVs) and their related technologies are becoming progressively vital in numerous domains. The word "antennas" (529) shows that communication systems are essential for drone operations. This makes sense when one thinks about how crucial it is for drones to send and receive data when monitoring from a distance or on a package delivery mission.

The terms "UAV" (497) and "drones" (437) are also very common, showing an abundance of research into different uses of UAVs, such as cargo transport, environmental monitoring or emergency assistance. Other keywords, such as "aerial vehicle" (275) and "unmanned aerial vehicle" (232), enhance the idea that UAVs are currently important in technology research. All these words suggest a focus on improving UAVs, including in pathfinding, more efficient energy use or instant decision-making.

Besides UAVs as such, the dataset also shows emerging trends in technology and society. For example, words such as "optimization" (73) and "integer programming" (12) show a high level of involvement of mathematics in optimizing route planning, schedules and resource use by UAVs. Terms such as "energy transfer" (95), "inductive power transmission" (74) and "battery" (29) hint at the challenges of extended UAV flight times and optimized charging.

We also see mentions of places such as "China" (44) and specific uses such as "remote sensing" (65) and "forestry" (27), which implies that China is leading in both research and application of drones that include city planning and natural resources management. Words such as "smart city" (20) and "sustainable development" (23) suggest that UAVs are part of making our cities smarter and helping us reach our goals for a more sustainable world. Overall, these frequently used words provide a good picture of the progression in UAV research. This field is striving to bring together different areas of knowledge to develop new ideas and solve real-world problems.

The relationship between the top recurring keywords, authors and countries obtained in R Biblioshiny is displayed in a three-field plot in Figure 8C.

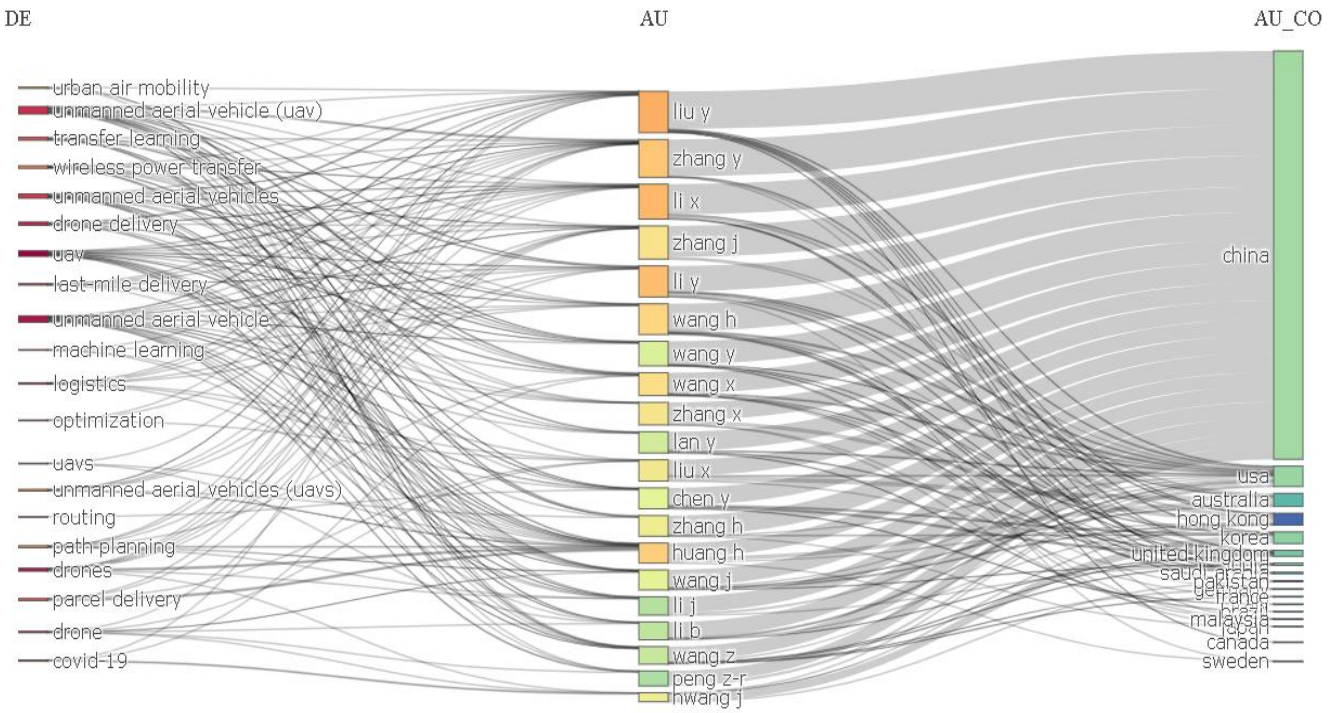

Figure 8C. *Three-field plot of top recurring keywords.*

Analysis of the picture reveals that keywords such as "urban air mobility", "unmanned aerial vehicle (UAV)", "transfer learning", "wireless power transfer", "drone delivery", "machine learning" and "logistics" are frequently

mentioned by scholars from various countries. The dominant country is China, with prominent authors that include Lan et al. (2021), X.-B. Li et al. (2018), Liu and Gao (2024), Poikonen et al. (2017), H. Wang et al. (2022), Y. Wang et al. (2022), J. Zhang and Li (2023), X. Zhang et al. (2021) and Y. Zhang et al. (2024). These authors have been engaged in research collaborations across countries such as the United States, Australia, Hong Kong, Korea, the United Kingdom, Saudi Arabia, Germany, France, Malaysia, Canada and Sweden, with authors that include H. Huang and Savkin (2021), Kim and Hwang (2020), B. Li et al. (2023), Peng et al. (2015), Veeranampalayam Sivakumar et al. (2020), J. Wang et al. (2023), H. Zhang et al. (2023) and Zhou et al. (2018). Visible from the plot is the fact that some authors are associated with multiple countries, possibly through collaborations or appointments. These researchers have made significant contributions to their respective fields by conducting studies that cover various aspects of technology and its applications, including the development of UAVs for urban air mobility, machine learning in logistics and the use of drones for last-mile delivery. They also explore the use of transfer learning to improve the efficiency of wireless power transfer systems, as well as optimization of routing and path planning for parcel delivery services.

5.3 Thematic areas

To exemplify the emerging threads in drone delivery research, a thematic map of the author keywords, as shown in Figure 9, is generated using the Bibliometrix package. A thematic map is a two-dimensional map obtained by plotting themes based on centrality and density measures to present keyword clusters along centrality (x-axis) and density (y-axis). The level of interaction of a network with other networks is denoted by centrality measures, while the internal strength of the network implies density measures (Wangsa et al., 2022). Based on these measures, the thematic map is arranged into four quadrants (Q1 – Q4).

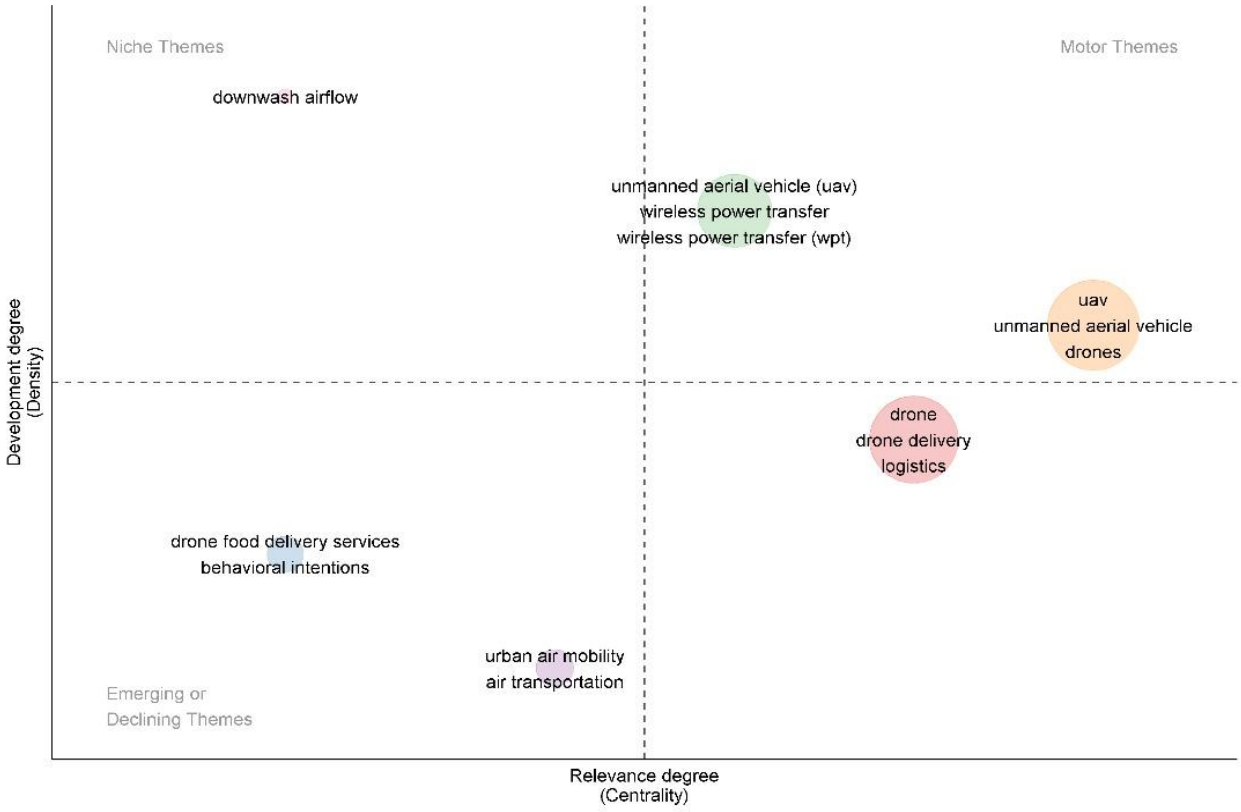

Figure 9. *Thematic map.*

5.3.1 Motor themes: Q1

Q1, located in the top-right portion of the diagram, contains themes with both high centrality and high density, representing well-developed and strongly connected areas of research. In this study, Q1 includes UAVs, drones and unmanned aerial vehicles. These themes constitute the core of drone delivery research, reflecting their central role in shaping both theoretical development and practical applications. They demonstrate strong internal cohesion

while also maintaining extensive connections to other areas such as logistics, optimization and last-mile delivery. The maturity of these themes indicates their importance as driving forces within the research landscape, forming the backbone of ongoing and future investigations.

5.3.2 Niche themes: Q2

Q2, located in the top-left quadrant, represents themes with high density but low centrality. These topics are internally strong but less connected to the broader research field, suggesting specialized or narrowly focused lines of inquiry. The themes in this quadrant include downwash airflow and wireless power transfer (WPT). These areas are technologically significant, often addressing engineering and operational challenges, yet they remain somewhat isolated from mainstream drone delivery discussions. For instance, research into downwash airflow explores aerodynamic effects critical for safety and operational performance, while wireless power transfer investigates sustainable energy solutions for drone operations. Their niche positioning suggests that these themes can contribute valuable technical insights, though their limited integration into broader research networks may restrict their immediate effect.

5.3.3 Emerging or declining themes: Q3

Q3, positioned at the lower left, captures themes with low centrality and low density. These topics are either in the early stages of development or are in decline. In this study, Q3 consists of drone food delivery services, behavioural intentions, urban air mobility (UAM) and air transport. The positioning of these themes indicates limited current integration into the wider research network, but their relevance points towards potential growth.

- Drone food delivery services represent a commercially driven application under exploration for feasibility and efficiency.
- Behavioural intentions highlight consumer acceptance, trust and perceived safety, which are crucial for adoption but remain underdeveloped in the literature.
- Urban air mobility and air transport suggest a forward-looking expansion of drone delivery into broader aviation and smart city contexts, including integration with air traffic management and multimodal logistics.

Collectively, these themes point to an emerging shift from technical efficiency towards social acceptance, regulation and ecosystem-level integration, signalling important opportunities for future research.

5.3.4 Basic themes: Q4

Q4, located at the bottom-right, consists of themes with high centrality but low density, making them fundamental to the field yet underdeveloped in terms of internal cohesion. In this study, Q4 includes drone delivery, logistics and related keywords. These themes represent essential concepts in the drone delivery landscape, forming the building blocks of the field due to their strong connections to other areas. However, their relatively low density indicates that the research addressing these topics is still fragmented and requires further conceptual consolidation. Strengthening these themes through more comprehensive theoretical frameworks and interdisciplinary collaboration could solidify their role as foundational areas in drone delivery research.

The thematic distribution across the four quadrants provides valuable insights into the structure and dynamics of drone delivery research. Q1 motor themes highlight the mature and central role of UAVs and drones; Q2 niche themes capture specialized yet less connected technical investigations; Q3 emerging themes reveal early but promising directions in consumer acceptance and urban integration; while Q4 basic themes emphasize foundational yet fragmented research streams. Together, these quadrants illustrate both the current state and future potential of drone delivery scholarship, identifying areas of maturity, specialization and opportunities for deeper exploration.

6 CONCLUSIONS

The emergence of modern-day drones represents the culmination of a complex evolutionary journey, marked by a transformation from military arsenals to useful civilian tools. This bibliometric analysis of drone delivery research, encompassing 1,438 articles obtained from the Scopus database articles published between 2015 and 2024 by 4,333 authors across 90 countries, highlights the rapid evolution and global impact of the field. The analysis, conducted using VOSviewer, ScientoPy and R Biblioshiny, reveals a steady publication growth from 10 articles in 2015 to 337 by October 2024, with citations rising from 7 to 7,726, yielding an H-index of 86. The exploratory phase (before 2015)

transitioned into a maturity phase after 2015, marked by a surge in publications and citations, further accelerated by the influence of the COVID-19 pandemic on drone delivery adoption. Geographically, Asia, led by China with 473 publications and a total link strength (TLS) of 247, dominates research output and collaborations, followed by the United States with 274 publications and a TLS of 177. Leading journals, particularly from Elsevier, IEEE and MDPI, with Drones journal topping the list at 83 publications, underscore the academic prominence of the field.

Advancements in drone technology, particularly in AI and machine learning, have revolutionized autonomous navigation, enabling drones to tackle complex environments and optimize energy efficiency. The emergence of drone swarms, using collective intelligence for tasks such as agricultural mapping and disaster response, represents a significant evolutionary trend. Sustainability remains a key driver, with drones reducing CO_2 emissions, traffic congestion and noise pollution, enhancing their appeal for last-mile delivery. Despite the dominance of advanced countries such as China, the USA and the UK in research and collaboration, contributions from South America and Africa remain limited, highlighting global disparities. As drone delivery research continues to mature, addressing challenges such as regulatory frameworks and equitable global participation will be critical to sustaining its transformative potential and ensuring broader societal benefits.

Drone technology has transformed logistics and delivery systems, evolving from military surveillance tools into versatile civilian applications. Early research laid the foundation for integrating drones into last-mile delivery, addressing challenges such as battery life, payload capacity and route optimization. Advancements in AI-driven navigation have enabled drones to autonomously navigate complex environments, while drone swarm technology offers scalability for tasks such as agricultural mapping and disaster response. These interdisciplinary innovations, combining engineering, computer science and environmental considerations, have driven academic progress and spurred industry adoption, with companies piloting drone delivery programmes to enhance efficiency in urban and rural settings.

Despite these advancements, scaling drone technology responsibly presents challenges. Drones offer sustainability benefits, including reduced carbon emissions, noise pollution and urban congestion, making them a promising alternative to traditional delivery methods. However, potential ecological disruptions, such as impacts on wildlife, alongside privacy and security concerns, require careful regulation and public dialogue. Hybrid models combining trucks and drones, along with AI-optimized flight paths, continue to improve efficiency, but balancing technological progress with societal and environmental responsibilities remains critical for the sustainable integration of drones into everyday life. In future studies, a specific application of drones in delivery services, such as medical delivery or food chain delivery, will be examined in depth. Analysis shall also include the institutional affiliations of authors.

ADDITIONAL INFORMATION AND DECLARATIONS

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Statement on the Use of Artificial Intelligence Tools: The authors declare that they didn't use artificial intelligence tools for text or other media generation in this article.

Data Availability: The data that support the findings of this study are available from the corresponding author.

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