Mapping the evolution of drone-based last-mile delivery: a bibliometric analysis with field insights from Colombia

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Abstract
The article combines a bibliometric analysis of 301 studies (2019–2025) with a survey of 70 Colombian logistics leaders. It identifies an annual scientific growth rate of 14.96 %, with emerging emphasis on sustainability, optimized routes, and hybrid truck-drone fleets. Respondents report key barriers: air-space regulation (80 %), limited payload capacity (65.7 %), insufficient infrastructure (64.3 %), and concerns about security, privacy, and high up-front costs. Integrating both approaches, the authors propose an urban pilot inspired by Milan, tailored to the Colombian context, profitable even at 50 % utilization and yielding a return above 90 % in the first year. They conclude that last-mile drone adoption demands clear regulatory frameworks, infrastructure investment, and risk-management strategies to build trust among users and operators.

Keywords: drones; last-mile delivery; Colombia; urban logistics; implementation barriers; sustainability.

Evolución de la entrega con drones en la última milla: análisis bibliométrico con enfoque en Colombia

Resumen
El artículo combina un análisis bibliométrico de 301 estudios (2019-2025) con una encuesta a 70 líderes logísticos colombianos. Detecta un crecimiento científico anual del 14,96 %, con énfasis emergente en sostenibilidad, rutas optimizadas y flotas híbridas camión-dron. Los encuestados señalan como principales barreras la regulación del espacio aéreo (80 %), la escasa capacidad de carga (65,7 %), la falta de infraestructura (64,3 %), además de preocupaciones sobre seguridad, privacidad y altos costos iniciales. Integrando ambos enfoques, los autores proponen un piloto urbano inspirado en Milán, adaptado al contexto colombiano, rentable incluso con una utilización del 50 %, generando un retorno superior al 90 % en el primer año. Concluyen que la adopción de drones en la última milla exige marcos regulatorios claros, inversión en infraestructura y gestión de riesgos para generar confianza entre usuarios y operadores.

Palabras clave: drones; entrega de última milla; Colombia; logística urbana; barreras de implementación; sostenibilidad.

1   Introduction

The exponential growth of e-commerce and consumers' expectations for fast and efficient deliveries have radically transformed logistics dynamics in urban environments. The so-called "last mile," understood as the final delivery leg from the distribution center to the end customer, currently represents one of the main operational, environmental, and economic challenges for distribution companies [1,2]. In Latin America, and particularly in Colombia, these challenges are exacerbated by structural conditions such as traffic congestion, uneven quality of urban infrastructure, and technological limitations of delivery fleets [3].

In this context, drones—or Unmanned Aerial Vehicles (UAVs)—are emerging as a disruptive technological alternative with the potential to transform last-mile logistics. Their ability to avoid traffic congestion, operate over short distances with greater energy efficiency, and reduce

environmental impact positions them as a viable and sustainable solution in urban and suburban settings [4,5]. However, implementing drones in the Colombian context requires overcoming various regulatory, technical, and social barriers, as well as adapting operational models to the country's geographic and demographic specificities [6,7].

Given this scenario, the present article aims to analyze the state of the art regarding the implementation of drones in last-mile logistics, with an emphasis on their applicability in urban areas of Colombia. To achieve this, a systematic review of recent international scientific literature (2019–2025) is conducted, considering technical, operational, regulatory, and environmental aspects. This analysis allows for the identification of major research trends, key challenges, and strategic opportunities for designing drone-based logistics solutions in the Colombian urban context.

This study also conducts a bibliometric analysis of drone use in last-mile deliveries, through an analysis of publications in Scopus [8] and a survey of logistics leaders in Colombia, offering a comprehensive view of the state of the art and contrasting local perceptions with global trends, to enable a deeper understanding of the topic.

2 Methodology

This research aims to conduct an exhaustive review of scientific literature and analyze the technical, legal, and environmental aspects related to drone technology. The study is framed as a descriptive and mixed-methods investigation, combining both qualitative and quantitative approaches. The methodology is based on previous research on the feasibility, barriers, opportunities, and challenges of using drones in last-mile logistics, adapted to the Colombian context.

2.1 Bibliometric analysis

This analysis aims to identify and synthesize global research trends and thematic priorities in the domain of drone logistics, with special attention given to last-mile delivery and its integration into urban environments.

It was structured into four methodological phases to ensure consistency and analytical rigor. First, the search criteria were defined using the Scopus database, selecting only peer-reviewed journal articles published between January 2019 and April 2025, using the following query: TITLE-ABS-KEY ("drone" AND "last mile delivery") AND (LIMIT-TO (DOCTYPE, "ar")). Second, metadata from 301 articles were extracted, including title, authors, affiliations, year of publication, abstract, author keywords, citation count, and corresponding author's country. The dataset was exported in a format compatible with Bibliometrix (RStudio). Third, data cleaning and standardization were performed, involving normalization of author and institution names, elimination of incomplete or duplicated records, and manual unification of semantically equivalent keywords. Finally, a comprehensive bibliometric analysis was conducted using Bibliometrix, which enabled the computation of descriptive metrics (e.g., annual scientific production, average citations, and collaboration rate), along with structural and network analyses such as thematic mapping, keyword co-occurrence, co-authorship and co-citation networks, and geographical distribution of scientific output.

2.2 Empirical survey on implementation barriers in Colombia

The survey was designed following the methodological guidelines proposed by [9] and aimed to assess the current state of drone use in last-mile logistics in urban Colombia.

The target population included companies and individuals involved in transportation and supply chain operations, particularly those familiar with drone technologies. The data collection was carried out through a structured survey, composed of 21 questions organized around six barrier categories adapted from [10]: privacy and security, regulatory, psychological, environmental, economic, and technical challenges. However, the conceptual framework for the survey also integrated insights from other recent studies on drone logistics adoption and diagnostic research methodologies [10-12].

A non-probabilistic convenience sampling method was used to select logistics professionals who were readily accessible and willing to participate [12]. The sample included 70 logistics process leaders from major Colombian cities such as Bogotá, Medellín, Cali, Barranquilla, Cartagena, and others. Notably, 85% of respondents had over five years of experience in logistics operations across various sectors, including freight transport, retail, e-commerce, pharmaceuticals, and courier services.

Before distribution, the survey underwent a content validation process through expert review by academics and professionals with at least a master's degree and experience in distribution logistics. The validated instrument was then deployed via Google Forms. To maximize reach and participation, a snowball sampling technique was also adopted [13], encouraging participants to share the survey within their professional networks, including via LinkedIn—mirroring the outreach strategy described by [9].

The empirical insights generated from this process allowed for a rich, context-specific understanding of the implementation barriers to drone-based last-mile delivery in Colombia, thereby offering a grounded counterpoint to the more generalized barriers identified in global literature.

3 Results

The bibliometric analysis was conducted on a curated dataset of 301 journal articles published between 2019 and 2025, retrieved from Scopus [8]. These documents were distributed across 138 different sources. Key descriptive indicators include an annual growth rate of 14.96%, an average document age of 2.17 years, and an average of 29.9 citations per document. A total of 12,963 references were analyzed. The dataset includes 871 unique author keywords and 1,693 Keywords Plus. A total of 927 authors contributed, with an average of 3.68 co-authors per document and an international collaboration rate of 32.56%.

These metrics reveal a growing and collaborative field, characterized by multi-authored contributions and a notable level of international scientific cooperation.

Scientific output showed a consistent upward trend over the seven-year period, peaking in 2024 and 2025. Authors such as Ghoniem A., Kong F., and Altinses D. were the most productive. The main journals published on this topic

included "Transportation Research Part E," "IEEE Internet of Things Journal," and "Expert Systems with Applications."

China, the United States, and the United Kingdom were the most prolific countries, reflecting strong investment in technological research and logistics innovation.

Highly cited articles addressed optimization problems, delivery models, and sustainability impacts. Among them, the paper titled "The multiple flying sidekicks traveling salesman problem" received 350 citations.

Collaboration networks revealed clusters of co-authorship primarily concentrated in Asia and Europe. The analysis of keyword co-occurrence identified core themes such as logistics, routing, optimization, and urban delivery. Recent years saw the emergence of terms like "sustainability" and "urban logistics," suggesting an increasing diversification of research agendas.

3.1 Evolution of scientific output over time

The temporal evolution of scientific publications on drones in last-mile delivery logistics, spanning from 2019 to 2025, reveals a strong upward trend in scholarly interest. In 2019, there were only 13 published articles; this number increased steadily in the subsequent years, reaching 25 in 2020, 26 in 2021, and 42 in 2022. A significant growth occurred in 2023 with 56 articles, culminating in a peak of 109 publications in 2024. As of April 2025, 30 articles have already been published, suggesting that the current year may surpass or match the previous year's total by the end of the period. This trend is illustrated in Fig. 1, which clearly reflects the exponential increase in academic output related to drone applications in urban logistics.

In terms of impact, measured by the average total citations per year, a declining trend is observed. While early publications in 2019 and 2020 achieved high citation averages (18.59 and 18.84 respectively), more recent publications such as those in 2024 and 2025 exhibit lower averages (2.28 and 0.10). This is expected, as newer articles typically require more time to accumulate citations. Nonetheless, the increase in output reflects a growing maturity and diversification of the field of research.
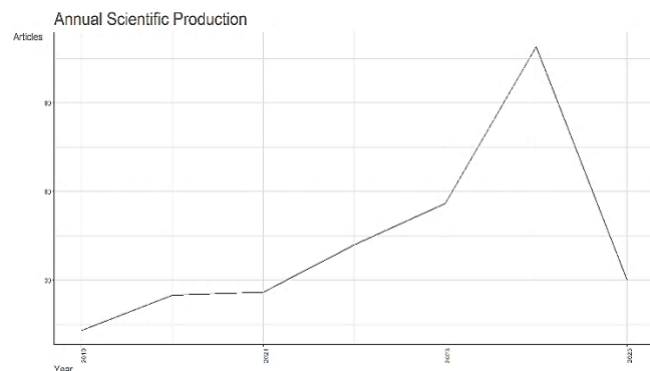

Figure 1. Annual Scientific Production.
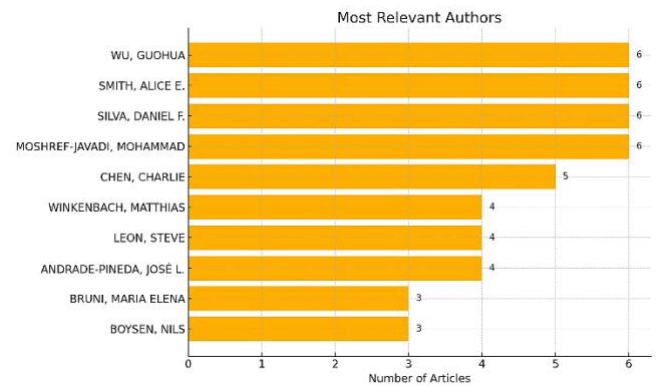Source: Scopus, 2025.

Figure 2. Most Relevant Authors.
Source: Scopus, 2025.

These findings underscore a progressive consolidation of drone-based delivery systems as a focal topic within logistics and transportation research, driven by both technological innovation and global interest in smart urban mobility solutions.

3.2 Most productive authors and institutions

The analysis of author productivity revealed that the most active contributors in the field of drones for last-mile delivery are Daniel F. Silva and Alice E. Smith. Both have contributed multiple articles between 2024 and 2025, including publications in top-tier journals such as *IEEE Transactions on Evolutionary Computation* and the *European Journal of Operational Research*. Their research focuses on optimization algorithms and logistics planning for truck-drone hybrid systems [14]. Fig. 2 visually highlights their leading roles, showing their high publication counts relative to other authors in the field.

Regarding institutional productivity, Central South University leads with 24 publications, followed by The Hong Kong Polytechnic University (22), National Technical University of Athens (21), and Beihang University (19). These institutions are predominantly located in Asia and Europe, reflecting the global distribution of drone-related logistics research hubs. Fig. 3 illustrates this ranking, emphasizing the dominant presence of Asian and European institutions in the scientific output on last-mile drone delivery.
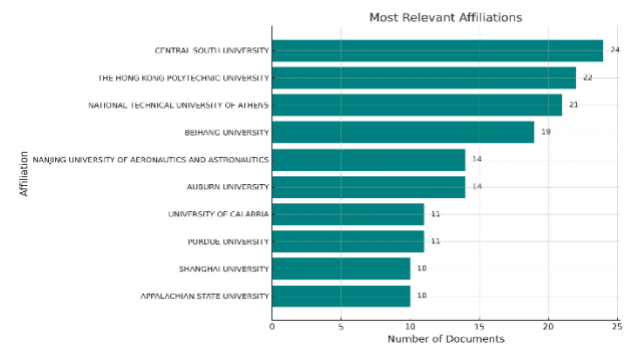

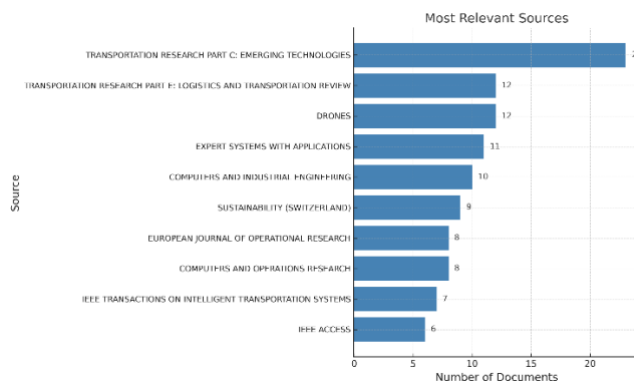Figure 3. Most Relevant Affiliations.
Source: Scopus, 2025.

Figure 4. Most Relevant Sources.
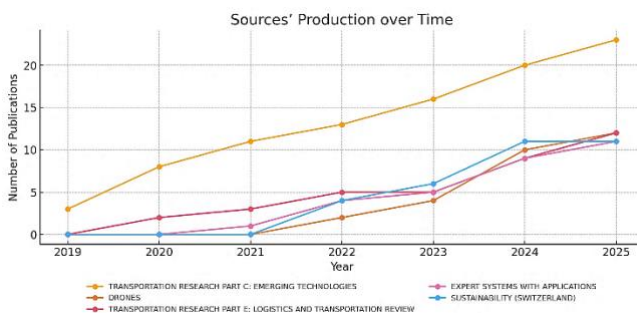Source: Scopus, 2025.

Figure 5. Sources' Production over Time.
Source: Scopus, 2025.

The data suggests that productive researchers are often embedded within highly active institutions, and their work is frequently published in high-impact journals. This correlation between author and institutional output underscores the importance of collaborative environments and research infrastructure in advancing the field.

3.3 Most relevant journals and thematic areas

The bibliometric analysis identified several academic journals that play a central role in disseminating research on drones in last-mile logistics. Fig. 4 presents the most relevant sources, highlighting Transportation Research Part C: Emerging Technologies as the most prolific, with 23 articles published on the topic during the 2019–2025 period. Fig. 5 complements this by illustrating the Sources' Production over Time, including Drones and Transportation Research Part E: Logistics and Transportation Review, each with twelve articles, and Expert Systems with Applications, which contributed eleven articles.

These journals indicate a multidisciplinary scope, where research, engineering, and intelligent systems intersect with logistics. Particularly, the prevalence of technology-focused and optimization-oriented outlets suggests that the field is still strongly driven by performance modeling, system design, and algorithm development.

The thematic areas addressed in these publications include autonomous vehicle routing, hybrid delivery
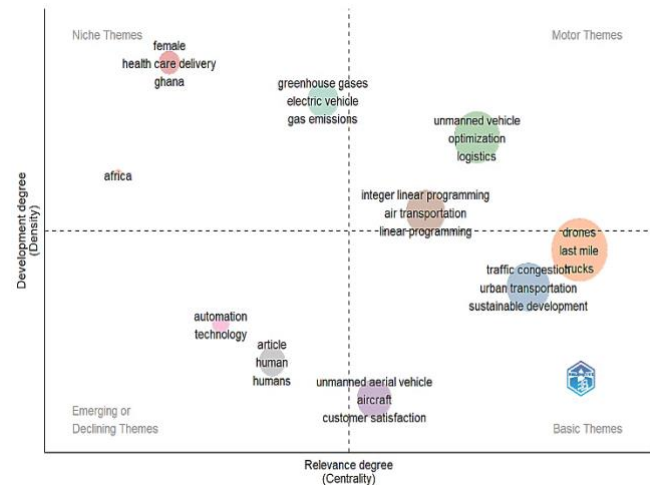

Figure 6. Thematic Map.
Source: Scopus, 2025.

systems, sustainability in logistics, and urban transportation networks. Fig. 6 displays the thematic map, which visually clusters these core areas based on co-word analysis, revealing the intellectual structure of the field. This diversity reflects an expanding academic interest in adapting drone technology to the practical challenges of urban distribution and smart city logistics.

While global academic literature frequently addresses drone logistics from the perspective of optimization and integration within smart urban systems, the work of [10] provides a valuable framework for analyzing the barriers to implementing drones in last-mile deliveries. Building on this, the fieldwork conducted in Colombia captures the perception of leaders in distribution and transportation logistics processes. Among surveyed logistics leaders, Fig. 7 illustrates security and privacy emerged as the most critical concern (68.6%).

These findings, particularly regarding risks such as hacking, cyberattacks, and physical interference with 77.1% also citing theft or damage to drones as shown in Fig. 8.
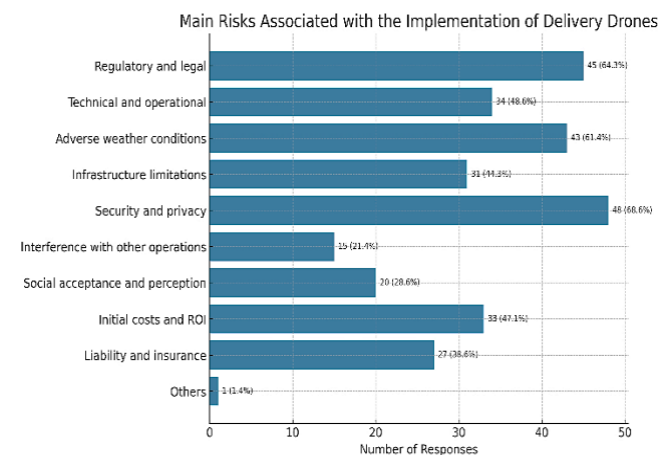

Figure 7. Most Critical Concerns.
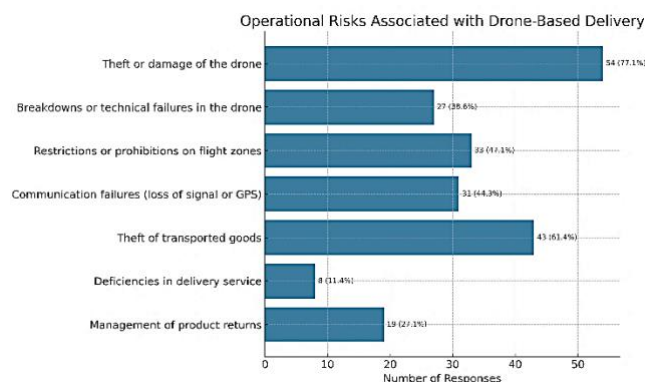Source: Own elaboration.

Figure 8. Most Critical Risk.
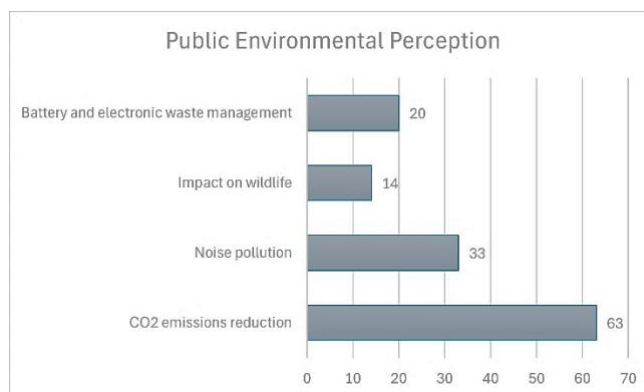Source: Own elaboration.

Figure 10. Public Environmental Perception.
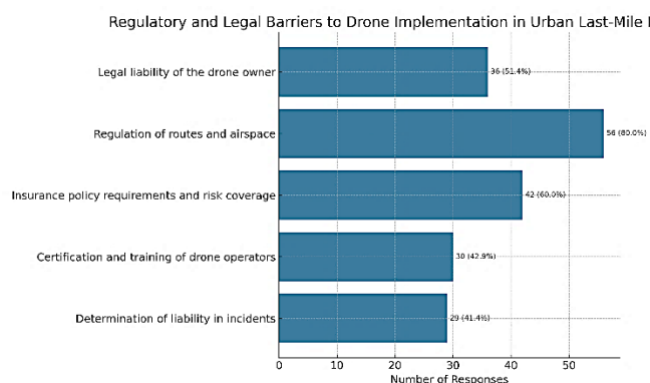Source: Own elaboration.

Figure 9. Regulatory Barriers.
Source: Own elaboration.

3.4 Keyword co-occurrence analysis

Figure 11. Co-occurrence Network.
Source: Scopus, 2025.

Regulatory hurdles were equally prominent, with 80% of participants identifying airspace regulation as a major constraint, and over 60% pointing to insurance and licensing requirements. Fig. 9 illustrates these regulatory barriers, emphasizing the need for clearer frameworks related to drone flight permissions, operator certification, and liability coverage in last-mile delivery operations.

Public perception posed additional resistance: 47.1% of respondents noted fear of accidents, and 34.3% questioned the reliability of drones. Fig. 9 illustrates these public perception challenges, showing that although 90% acknowledged the potential of drones to reduce CO_2 emissions, 47.1% expressed concern about noise pollution, and nearly 29% highlighted the issue of electronic waste.

From an economic standpoint, while 72.9% of logistics leaders expected drones to reduce operational costs, 41.4% identified high initial investment as a key barrier. Technological limitations were also evident: 65.7% of respondents considered load capacity insufficient, and 64.3% cited the lack of adequate infrastructure to support drone operations.

These findings contrast the optimism observed in global academic research by grounding the discussion in real-world barriers, as illustrated by Fig. 10. They highlight the multifaceted challenges that may inhibit the integration of drones into smart city logistics, particularly in emerging economies, where regulatory, infrastructural, and societal constraints are still prevalent.
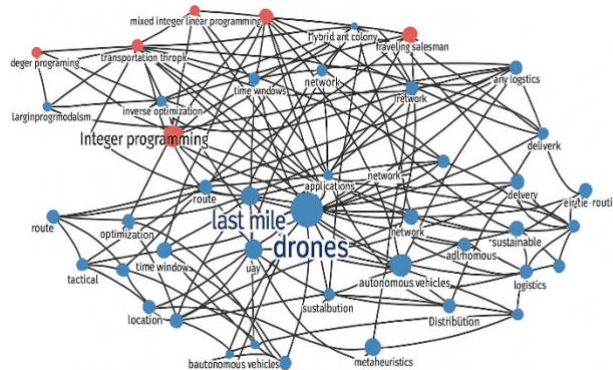
The analysis of keyword co-occurrence allows for the identification of the conceptual structure of the scientific literature on drones applied to last-mile delivery, by mapping the terms that most frequently appear together in indexed documents. This technique facilitates the detection of dominant themes, thematic connections, and emerging areas of research within the field. Fig. 11 presents the co-occurrence network, highlighting how clusters of related terms—such as optimization, routing, sustainability, and vehicle type—reveal the multidimensional nature of current research and its alignment with practical implementation challenges.

In this study, a co-occurrence network was constructed based on centrality metrics such as betweenness, closeness, and PageRank, which enabled the identification of the most influential nodes within the semantic network. The term "integer programming" emerged as the most central keyword, with a prominent score in betweenness centrality (49.3) and PageRank (0.057). This highlights the importance of mathematical modeling and algorithmic approaches as essential tools for solving complex logistical problems, particularly those related to route planning and resource allocation.
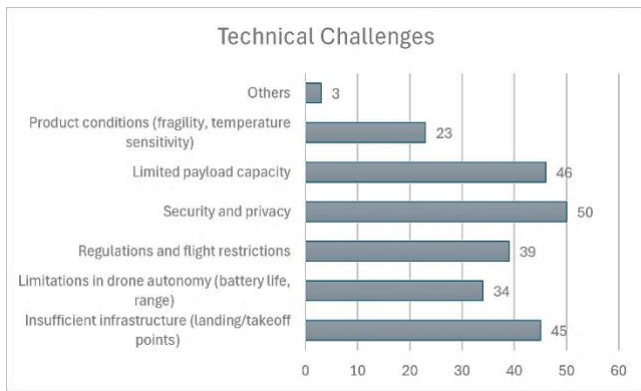
Figure 12. Technical Challenges.
Source: Own elaboration.

Figure 13. Co-citation Network.
Source: Scopus, 2025.

Other highly connected terms included "traveling salesman problem" [15], "automobiles," and "routing", all of which are grouped into a thematic cluster focused on operations research, logistics network optimization [16], and transportation analysis. These concepts reflect the central role of computational techniques in addressing efficiency challenges in urban deliveries, especially in scenarios where travel time [17], energy consumption [18] or carbon emissions [19], must be minimized.

This thematic structure directly echoes the findings from the fieldwork conducted in Colombia, where 70 leaders from logistics, manufacturing, and transportation companies were surveyed. Fig. 12 illustrates these technical challenges, revealing that the barriers to drone adoption for last-mile delivery are closely aligned with those identified in the academic literature: insufficient infrastructure (64.3%), limited payload capacity (65.7%), restricted drone autonomy (48.6%), and complexities in planning efficient routes in urban environments.

As a result, both academic research and business perception in the Colombian context converge on the idea that logistics optimization—understood as the integration of variables such as vehicle type, urban mobility conditions, and physical infrastructure constraints—is a top priority. The high interconnectivity among the key terms identified in the literature confirms that the field remains firmly rooted in quantitative models and algorithmic solutions, while the local empirical data reinforces the relevance of these approaches for addressing real-world implementation challenges of drones.

It is worth noting that although the thematic network is currently dominated by mathematical approaches, new keywords are beginning to emerge related to sustainability, public perception [16], regulations [20], and emerging technologies (such as AI and blockchain) [21], suggesting a gradual diversification in the analytical frameworks. This thematic evolution opens opportunities for future research to integrate both technical and social components into more holistic proposals for last-mile logistics design.

3.5 Co-authorship network analysis

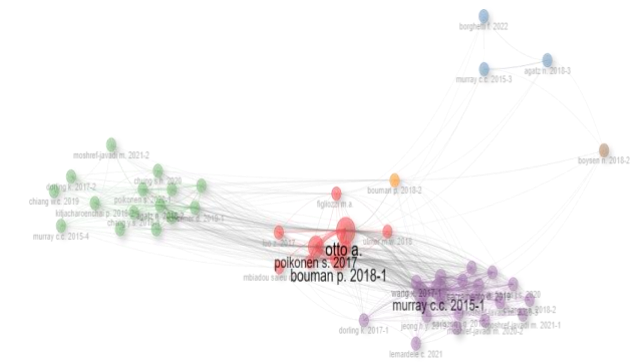Fig. 13 presents the co-citation network, offering insight into the structure of collaboration among researchers in the field of drones for last-mile delivery. Based on co-citation metrics and centrality indicators, the network highlights the most influential authors and the degree of their integration within the broader research community. This structure reveals not only the key intellectual contributors but also the formation of thematic clusters that shape the academic discourse on drone-based logistics solutions.

Otto A. emerges as the most central figure in the co-authorship network, showing the highest betweenness centrality (385.79), closeness (0.017), and PageRank (0.038). These metrics indicate that Otto A. plays a pivotal role in connecting different subgroups within the network. Other significant contributors include Bouman P. (2018), Poikonen S. (2017), and Figliozzi M.A., all of whom exhibit strong connectivity and influence.

The clustering of authors into distinct communities reveals thematic collaborations focused on vehicle routing, urban delivery frameworks, and algorithmic optimization. The presence of authors linked to foundational publications between 2017 and 2018 suggests that early contributions continue to anchor contemporary research.

Overall, the co-authorship structure demonstrates a moderately centralized network, with a few key authors acting as hubs of influence and collaboration. These hubs facilitate knowledge dissemination across research groups and support the consolidation of best practices in drone-based logistics.

3.6 Geographic analysis: countries with the highest production

The geographic distribution of publications reveals the countries that are driving research on drones in last-mile delivery logistics. Fig. 14 displays the distribution by corresponding author's countries, showing that the United States leads in scientific output with 57 publications, accounting for 18.9% of all documents in the dataset. It is followed by China with 49 publications (16.3%), while Italy, Germany, and the United Kingdom also figure among the most active contributors, reflecting a strong global interest concentrated in North America, Asia, and Europe.
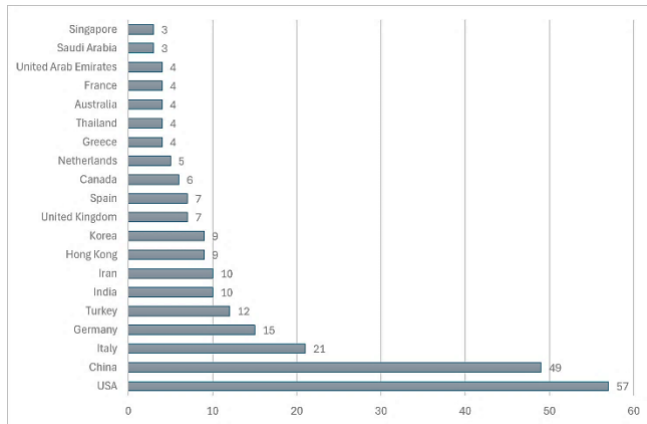
Figure 14. Corresponding Author's Countries.
Source: Scopus, 2025.

Figure 15. Most Global Cited Documents.
Source: Scopus, 2025.

A deeper look at collaboration patterns distinguishes between single-country publications (SCP) and multiple-country publications (MCP). The United States had 37 SCPs and 20 MCPs, while China had 32 SCPs and 17 MCPs, indicating a balanced mix of domestic and international research efforts. Notably, Italy showed a high proportion of international collaboration, with 42.9% of its articles involving authors from other countries.

These trends underscore the global nature of drone-related research, with significant contributions from both Western and Asian countries. The high level of MCP in countries like Italy suggests an openness to cross-border collaboration, which can be crucial for advancing experimental implementations and policy alignment in smart logistics.

Italy stands out as one of the leading countries in research on drone-based last-mile delivery, and a representative example of this leadership is the case study conducted in Milan by [22]. Through a stated preference analysis and financial evaluation, the study demonstrated that autonomous drones are both technically feasible and economically sustainable for small parcel deliveries in urban environments, achieving profitability within three years. This empirical evidence provides a solid methodological foundation for replicating similar models in other urban contexts.

Building on the foundational work by [22], a pilot project was formulated in this research to assess the applicability of drone-based last-mile delivery in Colombian urban areas. The Milanese model served as a benchmark, demonstrating both technical and financial feasibility under real-world constraints. The proposed pilot mirrors key operational parameters—including drone specifications (octocopter design, 2.25 kg payload, 30-minute autonomy), delivery cycles, and depot structure—tailored to Colombia's urban logistics conditions. The plan aims to conduct over 32,000 deliveries with a fleet of 10 drones, and incorporates performance indicators such as service precision, delivery time, operational efficiency, and environmental impact. Financial projections under pessimistic, moderate, and optimistic utilization scenarios show that the initiative is profitable even at 50% operational capacity, achieving a first-year return on investment exceeding 90%. These results underscore the viability of drones as a scalable and sustainable solution to the growing challenges of last-mile delivery in Colombian cities.

3.7 *Most cited documents*

The most cited documents in the field of drone applications for last-mile delivery provide insight into foundational contributions and thematic influence within the research community. Based on total global citations, the top five articles represent a combination of methodological innovation and system-level analysis.

Fig. 15 highlights the most globally cited documents in the field of drones for last-mile delivery. Leading the list is the article by [23], published in Transportation Research Part C: Emerging Technologies, which received 350 citations, with an average of 58.3 citations per year. This paper presents a robust framework for hybrid drone–truck delivery systems and has become a foundational reference in studies focused on optimization algorithms and simulation-based logistics models, underscoring its critical role in shaping the academic discourse.

Following closely is an article by Sacramento, which received 343 citations and focuses on stochastic modeling of drone-based logistics under uncertainty. Other notable contributions include works that explores routing efficiency and the integration of drone systems with urban infrastructure. These influential studies—by [24, 25, 4] have significantly advanced the theoretical foundations of drone logistics and continue to shape current research in the field.

These highly cited papers not only serve as methodological benchmarks but also signal the primary axes of development in this field: route planning, hybrid fleet coordination, and smart infrastructure integration. Their prominence underscores the technical depth and applied potential of research in last-mile drone logistics.

4 Discussions

The findings of this study allow for an integrated understanding of global research trends on drones for last-mile deliveries and the contextual perception of logistics leaders in Colombia. The bibliometric evolution shows a sustained growth in scientific production in the field, peaking in 2024, with an increasing focus on topics such as sustainability, energy efficiency, route planning, and hybrid truck-drone systems [23,4]. This panorama reflects a consolidating field driven by technological developments and the pursuit of more sustainable and resilient urban logistics models [26].

However, the contrast between international literature and the results of the survey applied in Colombia reveals a significant gap between theoretical potential and practical feasibility. While studies such as those by [22, 27] highlight the technical and economic feasibility of drones for fast deliveries in densely populated urban areas, Colombian logistics leaders point out critical obstacles such as limited payload capacity (65.7%), insufficient infrastructure (64.3%), and regulatory constraints (80%), which align with the barriers identified by [10, 20].

Furthermore, risk perception and social concerns —including privacy, safety, and noise— emerge as significant barriers. These findings align with research such as [28], who warns of the social and labor impacts of drone deployment in African healthcare systems, and the study by [29], which highlights the negative effect of perceived risk on consumers' adoption intention.

From a technical perspective, the predominance of terms such as "integer programming" and "traveling salesman problem" in the co-occurrence analysis of keywords confirms the literature's emphasis on using mathematical models and optimization algorithms as fundamental tools. This is consistent with proposals such as those by [30], who validate hybrid scenarios as more cost-effective depending on demand density and territorial configuration.

Regarding sustainability, the positive impact of drone use on carbon emissions is widely [26,18] and recognized by 90% of respondents. However, emerging environmental concerns persist, such as noise, electronic waste, and limited autonomy under adverse weather conditions [31,21].

The case of Zipline in Rwanda [32] serves as empirical evidence of the viability of well-structured operational models, capable of drastically reducing delivery times and eliminating the waste of medical resources. However, its replicability in Colombia requires institutional, regulatory, and technical adaptations, particularly in more complex urban environments with less regulatory coverage.

Finally, the implementation of a pilot inspired by the Milan model —adapted to Colombian conditions— represents a strategic advance. Its financial projections, even under pessimistic scenarios, suggest that sustainable returns are achievable. This result confirms the proposal by [33] on the scalability potential of drone delivery when supported by existing infrastructure and territorial planning.

Overall, this discussion reveals a critical duality: on one hand, academic and technical support for the viability of drones for urban deliveries; on the other, contextual barriers that still limit their effective adoption in countries like Colombia. Overcoming this gap will require a multi-stakeholder approach that articulates technological innovation, regulatory governance, urban infrastructure, and social acceptance.

5 Conclusions

The bibliometric analysis demonstrates the rapid consolidation of research on last-mile deliveries with drones between 2019 and 2025: scientific production has grown at an average annual rate of 14.96%, peaking in 2024, while diversifying towards topics such as sustainability, route planning, and hybrid truck-drone systems. These findings corroborate that urban aerial logistics has become a priority area within studies on smart mobility and emission reduction.

However, the survey applied to 70 Colombian logistics leaders reveals a gap between theoretical potential and practical adoption: 80% identify airspace regulation as the main barrier, 65.7% point to limited payload capacity, and 64.3% highlight the lack of support infrastructure. Additionally, concerns about security and privacy (68.6%) and the initial cost (41.4%) reinforce the need to address socio-technical factors before scaling pilot projects.

The integration of both approaches —bibliometric and empirical— enabled the proposal of a pilot project, inspired by the Milan case, adapted to Colombian urban conditions. Financial projections demonstrate profitability even at a 50% utilization level, achieving a return of over 90% in the first year, confirming the economic viability of the solution as long as supportive policies and infrastructure investment are articulated.

Among the study's limitations are convenience sampling and the self-reported nature of responses, which suggests caution when generalizing the findings. Future research should expand the sample to other stakeholders — aeronautical authorities, urban communities, and technology providers— as well as evaluate operational scenarios with demand simulations and climatic restrictions to strengthen decision-making.

Finally, although the literature supports the technical feasibility and environmental benefits of drones for last-mile delivery, their adoption in Colombia will depend on the ability to harmonize technological advancements with clear regulatory frameworks, adequate infrastructure, and risk management strategies that ensure trust among users and operators.

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