

AIoT-powered drones in the construction industry: a review

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Abstract

The digital revolution in construction is driving the nexus of emerging technologies. Technologies, such as the Artificial Intelligence of Things (AIoT), are transforming the sector by enhancing efficiency, promoting sustainability, and fostering innovation in construction projects. However, extant literature has failed to document integrated applications of Artificial Intelligence (AI) and Internet of Things (IoT). The interface of AIoT with drones and their applications in the construction industry is underreported. To address this gap, the current study systematically reviewed literature from the Scopus and Web of Science repositories to uncover the applications of AIoT-enabled drones. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocols were applied to review 33 highly relevant articles. The results show applications of AIoT-powered drones in various construction sectors such as land surveying and site selection, site layout, analytics and logistical planning, quality and progress monitoring, safety management, regulatory compliance, facility and asset management, and disaster management. Theoretical and practical implications, challenges, and future directions for research and industry to adopt AIoT-powered drones are reported. This study is a pioneering effort investigating the applications of AIoT-powered drones in the construction industry with equal benefits for researchers, academics, and industry practitioners

Key words: Artificial Intelligence, Artificial Intelligence of Things, construction, drones, Internet of Things, literature review

1. Introduction

The contemporary built environment has undergone a paradigm shift from traditional practices, driven by the application of disruptive technologies that encourage intelligent and sustainable development. Technological revolutions such as Industry 4.0 and Industry 5.0 are gaining traction in the construction sector as practitioners and stakeholders from the built environment prepare to embrace the impending advancements and innovations, marking a new chapter in the history of the construction sector (Musarat et al. 2023). Digitalization of the built environment has demonstrated several benefits for advancing sustainable development in the construction sector. Such digitalization highlights the importance of disruptive technologies in achieving ambitious global targets, such as the United Nations' Sustainable Development Goals (Azmat et al. 2023).

Drones are one such technology that has reshaped the norms of the construction industry owing to their diverse applications. Their impact is manifested across multiple stages of a construction project, encompassing sustainability, effi-

ciency, safety, and resourcefulness (Choi et al. 2023). As the construction industry rapidly transitions to digital technologies, the use of drones is expected to increase in the near future. In this context, researchers and industry practitioners are rigorously investigating the interface of drones with other technologies such as augmented reality (AR), virtual reality (VR), Artificial Intelligence (AI), Internet of Things (IoT), and computer vision (CV) in an effort to enhance their existing abilities and create opportunities for their new applications in the built environment (Elghaish et al. 2021). One such key technology is the Artificial Intelligence of Things (AIoT), which has emerged at the intersection of AI and the IoT.

AIoT is defined as “the convergence of AI and IoT technology where IoT fixates on data and AI as a set of analytical tools enables the extraction of value from data” (Ahanger et al. 2022). The integration of AI and IoT can create a transformative impact across industries by enhancing the existing data-capturing capabilities of IoT to leverage big data analytics and fostering human-machine collaboration to optimize processes and improve decision-making through innovation

(Marengo 2024). Some notable applications of AIoT involve video surveillance, autonomous vehicles, and autonomous delivery robots. In the construction sector, AIoT has found applications in fleet management, asset tracking, safety management, and wearable sensors (Baduge et al. 2022). However, the application of AIoT in the construction industry has been limited, which can be attributed to the relatively nascent nature of the research theme. Despite its limited implementation, the research and demonstrated outcomes of AIoT from other industries, such as manufacturing and agriculture, suggest its extensive potential advantages for the built environment. Leveraging AIoT in construction practices can lead to process improvement and innovation (Aliahmadi et al. 2022). In this context, the integration of AIoT and drones presents an attractive opportunity to revolutionize the built environment. Large amounts of data can be collected using drones and analyzed through AIoT to draw valuable insights that can be applied to revamp the planning, design, construction, and maintenance of constructed facilities.

Multiple studies in the past have aimed to document the opportunities presented by the nexus of drones and other technologies. Elghaish et al. (2021) investigated the intersection of drones and Building Information Modeling (BIM) technology through a critical review. They documented that remote project management can become a reality through the application of drones and immersive technologies. Rachmawati and Kim (2022) reviewed the application areas and technology trends of drones combined with extended reality in the construction industry. In a recent review, Singh et al. (2024) contextualized the application areas of drones integrated with virtual reality (VR) for earthworks and excavation monitoring. Garg et al. (2024) explored the concept of drones as a service (DaaS), assessing the combination of blockchain and IoT technologies to reveal their contributions to smart city infrastructure. Zhou and Gheisari (2018) reviewed the use of drones in construction, including building inspection, damage assessment, site surveying, safety inspection, progress monitoring, and building maintenance. However, no integration with other technologies was explored. Albeaino et al. (2019) reported the use of sensors, such as radio frequency identification and ultrasonic beacon systems, for progress monitoring. Greenwood et al. (2019) reported the application of drones for post-disaster reconnaissance, infrastructure component monitoring, geotechnical engineering, and construction management, as well as a network of sensors. Shakhathreh et al. (2019) reported critical challenges associated with drone applications, including collision avoidance, charging challenges, and swarming challenges, as well as security-related and networking challenges. Freeman et al. (2021) emphasized the engineering application of the drones, such as site management, maintenance, robotics construction, monitoring and inspection, and post-disaster survey. The highlight was the aerial robotics.

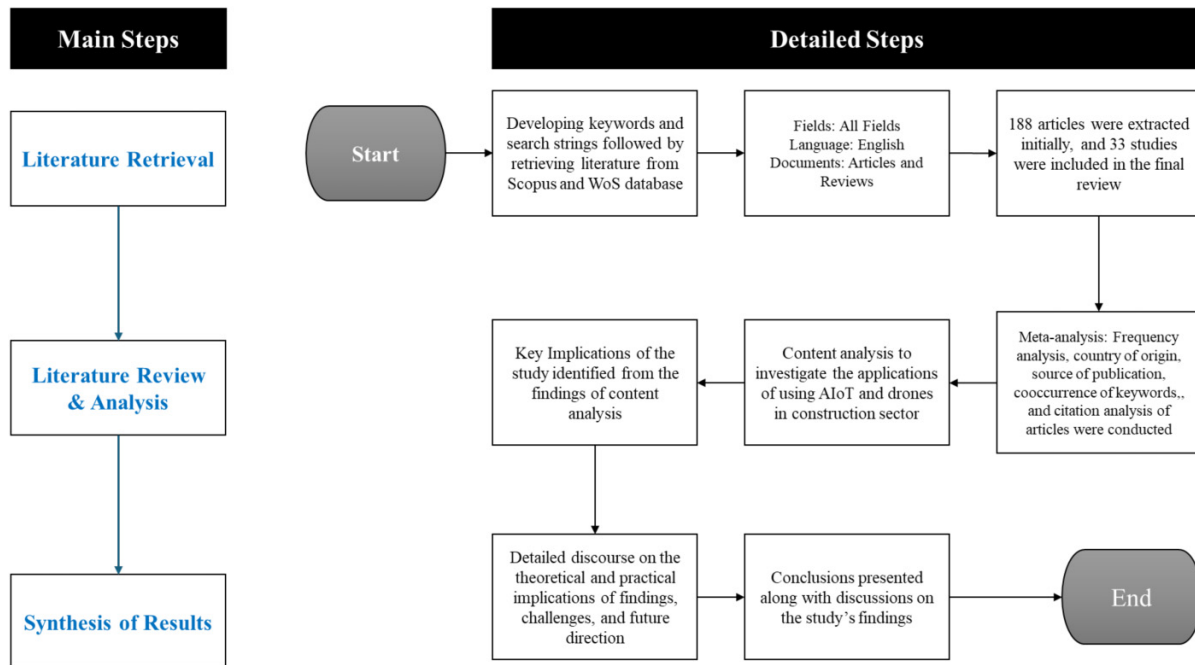
Recent review studies have attempted to contextualize the position of AIoT in the literature addressing construction. Yang et al. (2021) documented the current applications and future opportunities presented by AIoT technology in the environment monitoring for particles. Matin et al. (2023) dis-

cussed the trends and challenges in implementing AIoT technology in manufacturing, with an emphasis on modular construction and the potential contributions of AIoT to this approach. Heidari et al. (2024) conducted a systematic literature review (SLR) to assess the interoperability of BIM and AIoT with a focus on smart building management. Ouyang et al. (2024) discussed the intersection and advantages of AIoT and VR for smart robot control systems, aiming to advance safety management in critical environments. However, despite extensive studies conducted to consolidate the body of knowledge regarding drones and AIoT individually in the construction industry, based on the search retrieval protocols and holistic SLR process adopted in this study, no review study has been conducted to document the potential applicants enabled by the integration of AIoT and drones in the construction industry (Matin et al. 2023; Ouyang et al. 2024; Singh et al. 2024). A holistic review study investigating and documenting the applications of AIoT-powered drones in the construction industry is currently lacking in the prevailing literature. Some review studies have addressed the independent applications of AIoT and drones in the construction sector. No study, however, has investigated the potential areas of application emerging from the nexus of both technologies in the construction sector, presenting a significant literature gap. Accordingly, this study aims to analyze the applications of AIoT-powered drones in the construction industry. The current study addresses this research gap by conducting a comprehensive SLR to investigate and report the impact of integrating AIoT technology with drones and how it can reshape construction practices through novel applications.

The current study makes a novel contribution to the relevant literature, as no previous attempts have been made to review the nexus of both technologies (AIOT and Drones) and present their applications in the construction sector. The current study adopts a holistic approach to reviewing the relevant literature on AIoT-powered drones, aiming to shed light on an underexplored area of AIoT and drone technology. SLR is conducted in the study using the preferred reporting items for systematic and meta-analyses (PRISMA) protocol, owing to its extensive use in studies of a similar nature (Munawar et al. 2021; Sajid et al. 2024; Ullah et al. 2024). A bibliometric analysis is conducted to unveil metadata pertaining to the retrieved literature, followed by an in-depth content analysis to document the applications of AIoT-powered drones in construction. The study aims to inform academics and researchers of the built environment by drawing attention to this research theme and encouraging a rigorous exploration of different facets of AIoT-powered drones. The study also addresses industry practitioners in an effort to expedite the adoption of AIoT-powered drones in construction, aiming to revamp the norms of the construction sector.

The remainder of the study is organized as follows: Section 2 outlines the methodology employed for the review. Section 3 lists the SLR findings for both bibliometric and content analysis. Section 4 discusses the implications of the findings. Section 5 presents the conclusions drawn from the SLR conducted in this study.

Fig. 1. Methodology flowchart.



2. Methodology

The study conducts an SLR using the PRISMA protocol (Sarkis-Onofre et al. 2021). PRISMA is a process for documenting the findings of a systematic literature review, which researchers widely use due to its transparent and organized reporting of SLR findings. PRISMA eliminates the bias of authors and subjectivity in reporting evidence and selecting resources, which accounts for its extensive use in review studies conducted on different facets of the built environment. Ullah et al. (2024) employed the PRISMA protocol to conduct an SLR on the applications of G-IoT in the construction industry. Sajid et al. (2024) also employed this approach to document the barriers to circular procurement in the construction industry. PRISMA is effective in exploring the intersection of multiple technology domains (Kostadimas et al. 2025).

Articles addressing the research theme of AIoT-powered drones were sourced through a multi-step approach, as illustrated in Fig. 1. In the first step, scientific databases such as Scopus and Web of Science (WoS) were used to retrieve literature on the research theme broadly. Search strings composed of relevant keywords were devised and employed to extract relevant literature. The guidelines established by Ullah et al. (2021) in their studies on relevant research themes were employed to ensure conformity to the procedure of the PRISMA protocol. In the second step, a preliminary bibliometric analysis was conducted to identify metadata related to the relevant studies. In a bibliometric analysis, frequency analysis, country of origin analysis, keyword co-occurrence analysis, and citation analysis were performed to identify different trends related to the research theme. In the last step of the study, content analysis was performed to document the applications of AIoT-powered drones in construction, their implications, challenges, and future directions.

2.1. Research strategy

The study conducted SLR conforming to the PRISMA protocol, which entailed the following steps for literature retrieval, analysis, and synthesis of results:

1. The first fundamental point of PRISMA, which includes “protocol and registration”, was addressed by using keyword-based search strings to retrieve literature from the Scopus and WoS repositories. A time frame limit has not been applied to the search string to allow the retrieval of a maximum number of articles addressing the research theme (Ullah et al. 2024).
2. All the studies entailing the designated keywords in their title, abstract, or introduction were considered for the review, thereby abiding by the second protocol of PRISMA, which addresses “eligibility criteria”.
3. The “information sources” used for the study included the Scopus repository (scopus.com/search/form.uri?) and the WoS database (<http://webofknowledge.com/>).
4. The fourth point, which addresses the “search process”, was satisfied by including search strings, which are listed in Table 1.
5. The fifth point of PRISMA entailed the “study selection process”, which involved searching for articles on relevant research themes using specific search strings, screening irrelevant articles based on qualitative analysis, and removing duplicates.
6. The seventh aspect of PRISMA, titled “data items”, was addressed by performing bibliometric analysis and reporting the metadata pertaining to the studies. Content analysis was also performed on the shortlisted articles to satisfy this requirement.

Table 1. Search strings and their results.

Search engine	Search strings	Initial results (without filters)
Scopus	TITLE-ABS-KEY ("Artificial Intelligence" OR AI) AND TITLE-ABS-KEY ("Internet of Things" OR "IOT") AND TITLE-ABS-KEY ("Drone" OR "UAV" OR "Unmanned Aerial Vehicle") AND TITLE-ABS-KEY ("Construction Industry" OR "Construction Project" OR "Construction Management" OR "Construction Site" OR "Construction" OR "infrastructure" OR "Road")	155
Web of Science	"Artificial Intelligence" OR AI (All Fields) and "Internet of Things" OR "IOT" (All Fields) and "Drone" OR "UAV" OR "Unmanned Aerial Vehicle" (All Fields) and "Construction Industry" OR "Construction Project" OR "Construction Management" OR "Construction Site" OR "Construction" OR "infrastructure" OR "Road" (All Fields)	33
Sum of Papers		188
Duplicates		6
Total		182

7. The aspect of "bias" in the study was mitigated by using open-ended keywords and avoiding any restrictions on studies based on their country of origin, disciplines, and non-inclusive keywords.
8. The ninth aspect, addressing "summary measures", was handled by categorizing the findings from the analyzed articles into individual themes.
9. The study's findings regarding the applications of AIoT-powered drones and their implications, challenges, and future directions accounted for the 10th aspect of the PRISMA protocol, termed the "synthesis of the results".

The subsequent section provides a detailed explanation of the data collection and analysis strategies employed in the study.

2.2. Data collection and analysis

Semantic search strings composed of keywords were used to retrieve relevant articles from Scopus and WoS. The keywords were carefully crafted to maintain the focus area and theme of the study. The main keywords employed in the study were "Artificial Intelligence", "Internet of Things (IoT)", "Drones", and "Construction", which were used in various combinations to retrieve literature. Boolean operators, namely "AND" and "OR", were used to create the semantic search strings. The developed search strings for both Scopus and WoS are listed in [Table 1](#). As seen in the search strings, the retrieved articles were limited to the studies published in the English language only. Only journal outlets, including articles and review papers, were considered in the study ([Masood et al. 2022](#)). This choice was primarily inspired by the limited peer review involved in scrutinizing conference papers and book chapters.

A total of 188 articles were retrieved from both repositories, comprising 155 articles sourced from Scopus and 33 from WoS. After applying filters to exclude conference articles and book chapters and limiting the studies to original articles and review studies, 136 articles from the Scopus database remained, whereas 25 articles were retrieved from the WoS repository ($n = 151$). Following an initial screening, articles were deduplicated, and six studies were identified and removed from the review process. A total of 145 studies remained following the removal of duplicates. Subse-

quently, a thorough screening of the articles was conducted by reading the abstract, introduction, and conclusion sections of the retrieved studies. During thorough screening, the articles were limited to 40 relevant studies by removing literature that did not strictly concentrate on the concerned research theme. Lastly, the remaining studies showing a strong relevance to the concerned theme were chosen for in-depth review, whereby full texts of the articles were examined to validate their superiority. The scope of the study is to explore the intersection of AI, IoT, and drones. The authors identify the integration of direct and indirect technologies for the application within the field. Finally, 33 articles were included in the review, listed in [Table A1](#) of [Appendix A](#), due to their close alignment with the research topic. The PRISMA flow diagram in [Fig. 2](#) gives a visual summary of the screening process.

The data analysis conducted in the study broadly entailed bibliometric analysis and content analysis. The bibliometric analysis aimed to reveal the metadata associated with the studies. Different analyses, such as country of origin, frequency analysis, source analysis, keyword co-occurrence, and citation analysis, were performed. [Table 2](#) summarizes the various types of analysis performed and the tools used, including Scopus Analyze, VOSviewer, and MS Excel. For frequency analysis, source of publication, and country of origin analysis, "Scopus Analyze" was used to retrieve data, and MS Excel was used for visualizing the results. For keyword co-occurrence and citation analysis, the retrieved articles from Scopus and WoS were analyzed using VOSViewer. The authors used the full counting method to count the number of keywords and citations. Due to the limited number of studies available, resulting from the novelty of the research theme, the minimum limits for keywords and citations were set at 10 for Scopus and 5 for WoS. This practice aligns with previous studies on similar research themes ([Ullah et al. 2021](#); [Masood et al. 2022](#)). Consequently, 63 keywords and 2150 citations were identified for Scopus. For WoS, six eligible keywords and 343 citations were detected in total.

For content analysis, all shortlisted studies were downloaded in portable document format and thoroughly reviewed by the authors. The authors identified different areas of application for AIoT-powered drones through thematic analysis. The study's findings, which documented the contribution of AIoT-powered drones to each area, were recorded

Fig. 2. PRISMA flow diagram.

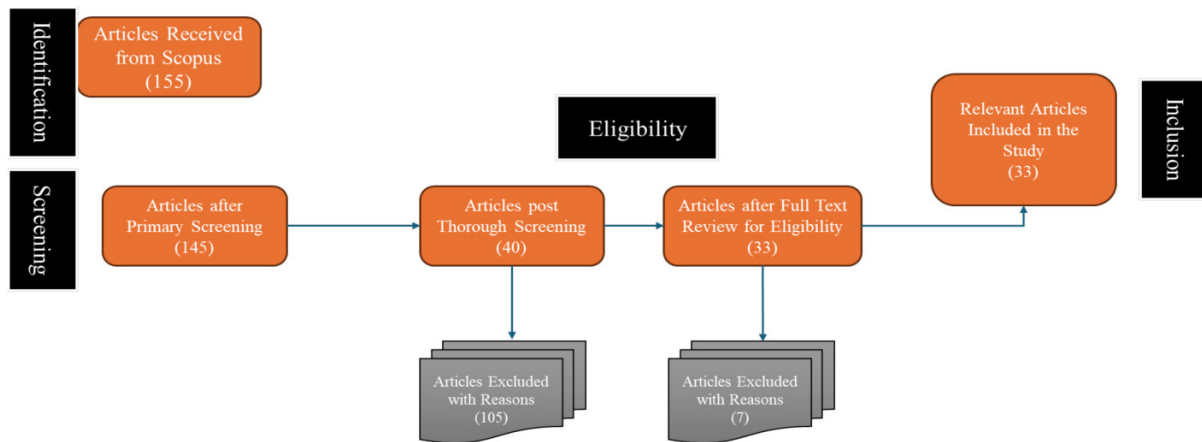


Table 2. Types of bibliometric analysis conducted.

Type of Analysis	Output	Tools	
Frequency analysis	Number of papers published per year addressing MC and CC mitigation	Scopus Analyze	MS Excel
Source of publication	Number of articles published by various journals pertaining to MC and its impact on CC	Scopus Analyze	MS Excel
Country of origin analysis	Number of articles regarding MC and CC originating from different nations	Scopus Analyze	MS Excel
Keyword co-occurrence analysis	Commonly occurring research themes based on keywords	Scopus Analyze	VOSviewer
Citation analysis	Number of citations received by the retrieved studies	Scopus Analyze	VOSviewer

in an MS Excel sheet. As part of the content analysis, key implications of the findings were also assessed, along with the challenges to the adoption of AIoT-powered drones in the construction sector. Finally, the authors proposed future directions based on the conducted SLR to inspire future research on the research theme and encourage the adoption of AIoT-powered drones in mainstream construction.

3. Results

3.1. Meta-analysis

Frequency analysis was the first analysis conducted as part of the bibliometric assessment. Figure 3a illustrates the results of frequency analysis. The first study on the research theme was published in 2016, which highlights the nascent nature of the research topic. The research theme experienced a steady trend until 2019 when it reached 10 publications. In 2020, a slight dip was witnessed as nine studies were published, which can be explained by slow research progress in the backdrop of COVID-19 (Jones et al. 2020). A steep increase in publications was witnessed in 2021 and 2022, with 38 and 31 publications, respectively, which can be explained by a recorded increase in digitalization in the backdrop of COVID-19 (Jones et al. 2020). Interestingly, the research trend achieved its peak in 2023 with 40 publications.

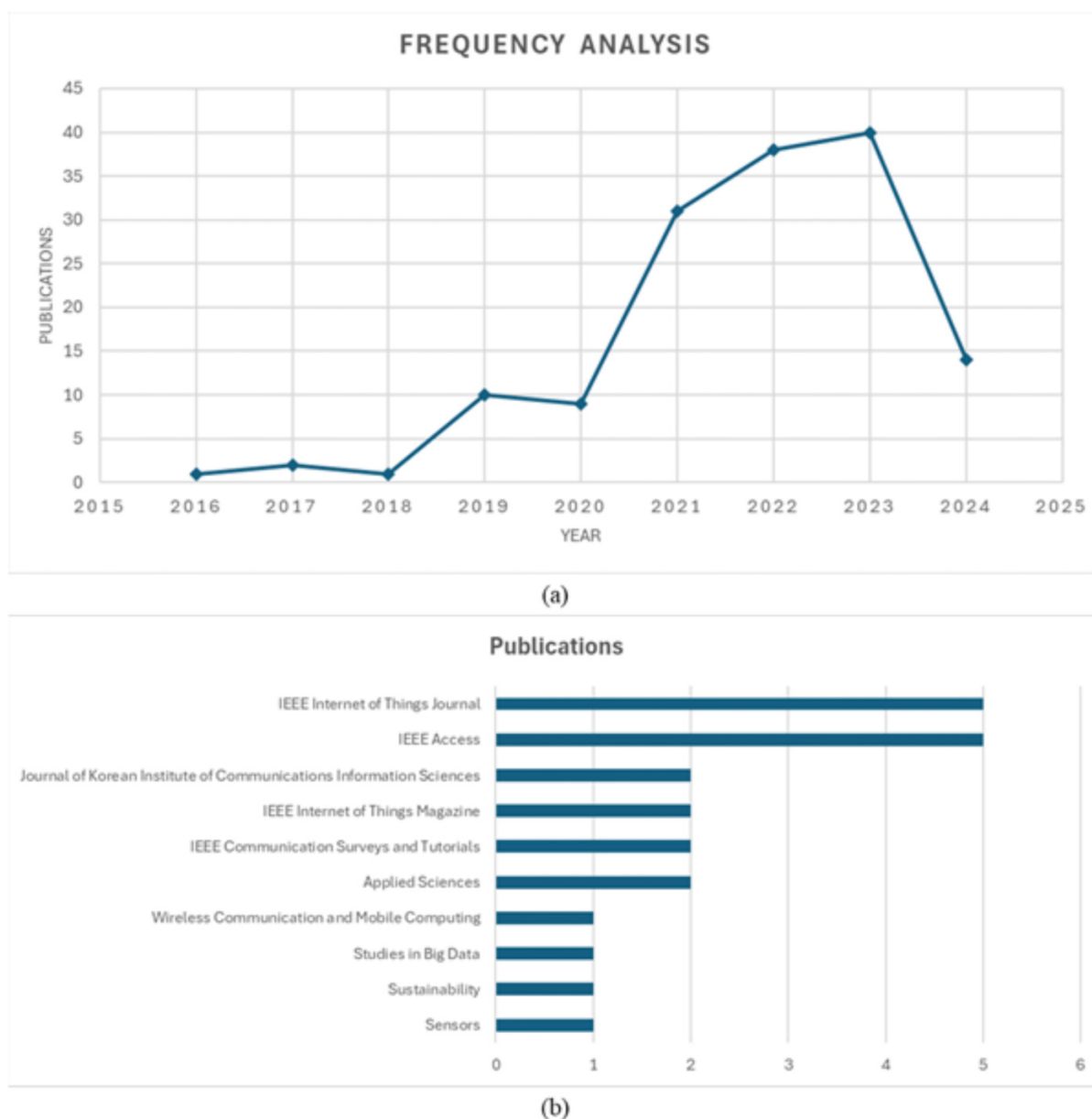
The journal or publication analysis was the second part of the bibliometric analysis, in which the journals that had con-

tributed most extensively to the research theme were identified. The results of the source analysis are presented in Fig. 3b, which shows that “IEEE Internet of Things” and “IEEE Access” are the highest contributors to the field, with five publications each. Being listed as Q1 in Scimago journal rankings, the interest in these high-quality journals indicates the significance of the research theme. “Applied Sciences Switzerland” and “IEEE Internet of Things Magazine” assume the second spot, along with “IEEE Communications Surveys and Tutorials” with two publications.

The country-of-origin analysis was conducted to identify the research trends and outputs of different nations related to the research theme. The results of this analysis are presented in Fig. 4. India was found to be the top contributor to the research theme, with a total of 41 publications. The high research output of India in this field can be explained by its recent investments in the IT sector, which sparked academic interest in investigating different facets of IoT and their intersection with other fields (Rejeb et al. 2023). The USA and China followed up with 26 and 20 publications, respectively, due to their strong IT sectors and extensive focus on digitalization in the construction sector (Sajjad et al. 2023). Other notable contributors include the United Kingdom (12), South Korea (12), and Canada (10).

The keyword co-occurrence analysis, conducted using VOSviewer, revealed the keywords that were most frequently used in the retrieved studies for both Scopus and WoS. Based

Fig. 3. (a) Results of frequency analysis (2016–2024) and (b) results of source analysis (2016–2024).

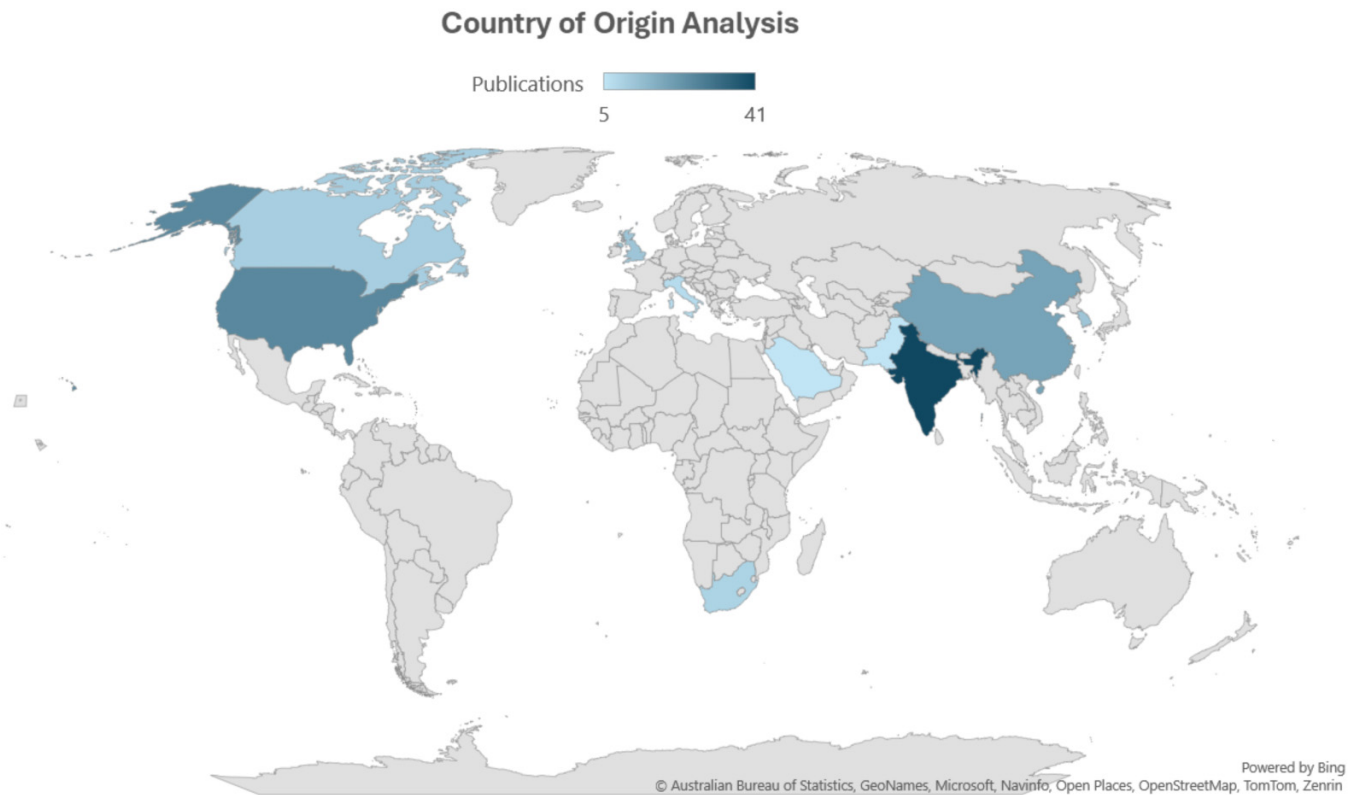


on the minimum criteria of 10 and 5 occurrences for Scopus and WoS, respectively, 19 and 6 keywords were identified for both repositories. The results of the most frequently occurring keywords are presented, and the highest occurring keywords are listed in Table 3. The highest occurring keyword for Scopus was determined to be “Internet of Things”, with 67 appearances. “Unmanned Aerial Vehicles” followed up with 54 appearances. Whereas “Artificial Intelligence” and “Antenna” followed with 43 and 41 appearances, respectively, in Scopus. In WoS, the keywords “Internet of Things”, “Unmanned Aerial Vehicles”, and “Artificial Intelligence” were found to be the most frequently occurring, with 16, 14, and 5 occurrences, respectively.

Based on the keywords, a scientometric map was developed to illustrate the position of keywords in literature as well as their link strength with other keywords. For the map

produced for Scopus, which is visible in Fig. 5a, four clusters are represented by distinct colors. The red cluster focuses on the Internet of Things, the yellow cluster represents decision-making, the green cluster represents UAVs, and the blue cluster addresses various themes related to the IoT. The central location of keywords such as “Internet of Things”, “Artificial Intelligence”, and “machine learning” shows their higher link strength with the overall literature. The map developed for WoS is visible in Fig. 5b, where only two clusters are formed. The red and green clusters share themes related to AI, IoT, and UAVs, suggesting a close relationship between these technologies. Limited clusters in WoS are a product of the limited number of studies retrieved from the repository as compared to Scopus.

Finally, the documents with the highest number of citations were analyzed, and their results are presented in

Fig. 4. Country of origin analysis.**Table 3.** Top keywords with the highest number of appearances.

Top keywords (Scopus)	Occurrences	Top keywords (WoS)	Occurrences
Internet of Things	67	Internet of Things	16
Unmanned Aerial Vehicles	54	UAV	14
Artificial Intelligence	43	Artificial Intelligence	5
Antennas	41		

Note: WoS, Web of Science.

Fig. 6. The scientometric mapping of the Scopus database is richer and shapes more clusters than WoS. Colours differentiate the knowledge clusters, and the thickness of the lines among the keywords defines the strong relationship (Masood et al. 2022). Two dominant clusters are red, which comprise the core keywords linked to machine learning, Industry 4.0, deep learning (DL), and 5G mobile communication systems. However, the green cluster showed key links with antennas, aircraft detection, aerial vehicles, and network security. The yellow cluster has the core keyword “decision-making”. The trend appears to be that AI and IoT concepts support drone technology, which dominates the research areas investigated.

In Scopus, the study by Chen et al. (2019) is listed as the most highly cited document, with 625 citations, as shown in Fig. 6a. This is followed by Vaezi et al. (2022), whose study received 196 citations, including self-citations. Studies by Yang and Yoo (2018), Khan et al. (2020), and McEnroe et al. (2022) were listed as other top-cited studies from Scopus. In WoS, a study by Vaezi et al. (2022) was listed as the top-cited study

with 145 citations, followed by Kuru (2021), which received 32 citations, as shown in Fig. 6b.

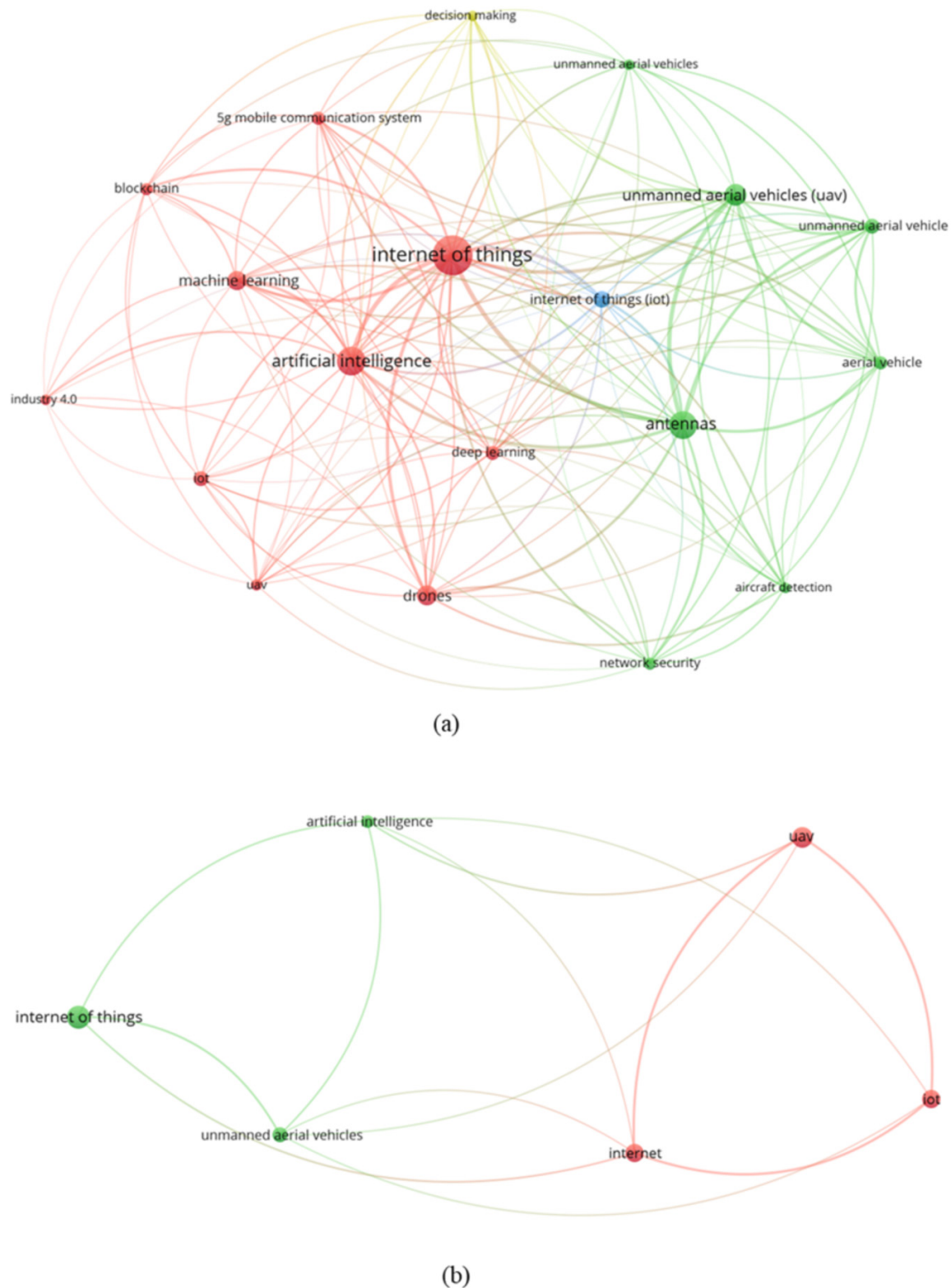
3.2. Content analysis

Content analysis was conducted by reading the full texts of the retrieved articles and compiling the findings from the reviewed articles. Content analysis revealed seven application areas for AIoT-powered drones in construction based on frequency and unique coverage, which are (1) land surveying and site selection, (2) site layout and logistical planning, (3) quality management and progress monitoring, (4) safety management, (5) construction site analytics and regulatory compliance, (6) facility and asset management, and (7) disaster management. A detailed discussion of each application is provided in the subsequent sections.

3.2.1. Land surveying and site selection

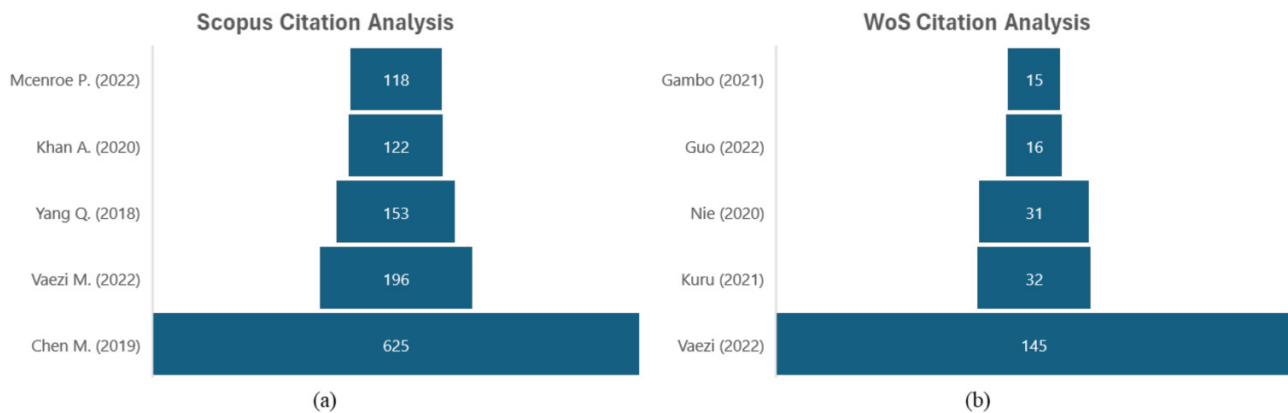
Drones have been used increasingly in recent years for land surveying operations owing to their demonstrated

Fig. 5. (a) scientometric map of Scopus keywords and (b) scientometric map of WoS keywords.



advantages over traditional means of site surveying (Choi et al. 2023). Comprehensive perspectives provided by the aerial imagery of drones inspire enhanced assessment of a construction site's topography, adjacent environment, and surroundings (Choi et al. 2023). However, studies have suggested that integrating AIoT and drones can further improve surveying

in construction projects. One of the predominant ways AIoT-powered drones can do so is through image recognition and computer vision, which can allow drones to prepare accurate and detailed 3D models of the surveyed land by automatically identifying different elements of the topography captured in aerial imaging (Caballero-Martin et al. 2024). Based

Fig. 6. (a) Citation analysis of Scopus documents, and (b) citation analysis of WoS documents.

on the developed 3D models, AIoT-powered drones can establish optimal survey control points, translating into accurate georeferencing and enhanced precision in mapping subsequently (Caballero-Martin et al. 2024). Another facet of AIoT-powered drones that can add significant value to land surveying is their ability to automate operations, thereby enhancing the efficiency of the surveying process. Traditionally, the aerial photographs captured by drones are manually overlapped to create 2D and 3D maps of the surveyed land. However, integrating AIoT can automate this process by stitching together multiple images through its photogrammetry algorithms, leading to improved efficiency and time-saving (Quamar et al. 2023).

Moreover, AIoT-powered drones can create ortho-mosaic maps in real-time, offering precise representations of the surveyed sites. AIoT-powered drones can also revamp asset inventory management by mapping the position of existing constructed facilities, infrastructure, and natural land, allowing developers to take them into account during decision-making (Alahi et al. 2023). Therefore, effective land use can be achieved in the built environment, thereby preserving the natural environment. Asset inventory management through AIoT-powered drones can also reveal insights regarding the potential impacts of constructing a new facility on its adjacent structures, enabling informed interventions to be employed to ensure their safety during construction (Whitehurst et al. 2021).

In addition to revamping land surveying, the integration of AIoT and drones can also enhance construction site selection by providing rich information regarding the characteristics of a prospective location (Bibri et al. 2024). AIoT-powered drones can assess the accessibility of the construction site by taking into account considerations such as roads, utilities, and surrounding buildings to unveil the constructability of the planned facility. Similarly, AIoT-powered drones can be leveraged to perform risk analysis on a construction site, revealing its susceptibility to risks such as soil erosion, landslides, and floods. Slope and elevation mapping combined with continuous reconnaissance of a location through AIoT-powered drones can reveal its susceptibility to landslides. Ground penetrating radars mounted on AIoT-powered drones

can detect sinkholes and underground anomalies that can potentially lead to structural collapse (Sun et al. 2024). The patterns of nearby water bodies can also be studied using this technology to evaluate flood risk to the facilities, especially in low-elevation regions. Environmental impact assessments (EIA) can also be enhanced through AIoT-powered drones, rendering sustainable land use. The AIoT-powered drones can use machine learning algorithms to predict the impact of land clearing and deforestation on local vegetation. It also creates opportunities for assessing carbon sequestration through an automated assessment of vegetation density surrounding the construction site and estimating the amount of embedded carbon (Subeesh et al. 2024).

Consequently, the impact of the construction site on carbon footprint and local climate can be predicted, leading to improved decision-making for sustainable development. Similarly, the potential effects of real estate development on nearby waterbodies, such as changes in hydrological patterns and water quality due to pollution, can be detected before construction to evoke necessary interventions for the preservation of waterbodies (Sharma et al. 2022). AIoT-powered drones can perform landscape change detection, unveiling the impacts of construction on historical and cultural sites, thereby advancing improved preservation strategies. The final contribution of AIoT-powered drones in construction site selection is the integration of historical data to reveal details about past land use, previous constructions, and recorded environmental events, providing a comprehensive understanding of the site's history and potential future issues (Irizarry and Costa 2016). AIoT-powered drones can enhance construction site selection by providing detailed insights into a site's accessibility, constructability, environmental impacts, inherent risks, and future challenges. This can lead to improved construction design and operations.

3.2.2. Site layout and logistical planning

An efficient construction site layout can improve on-site logistics, equipment use, and overall productivity of construction operations. Employing drones for construction site layout has yielded improved efficiency in layout planning

for construction sites, and integrating AIoT in the process can further enhance the value generated by drones. AIoT-powered drones can ensure the precise setting out of a construction site by comparing the actual location of building elements to their planned location in real-time. By establishing 3D models of the surveyed land, drones integrated with AIoT can assist surveyors in quickly and accurately setting up construction sites to develop an efficient layout in a short period (Zhang et al. 2021). Moreover, leveraging AI algorithms, AIoT-powered drones can predict the optimal location for the placement of equipment such as cranes, thereby streamlining their operations and reducing their working hours to conserve fuel (Yu et al. 2023). Similarly, they can assist in planning the path of construction equipment, such as bulldozers and dump trucks, to reduce the number of round trips, minimize idling time, and shorten travel distances, thereby enhancing the equipment's performance. Potential conflicts in the travel paths of equipment and machinery can also be evaded by AIoT-powered drones, which can simulate different scenarios on the basis of the travel patterns of construction equipment to highlight potential conflicts, translating into improved communication and coordination in logistical processes (Li et al. 2022).

They can also identify the optimal location of on-site storage structures to ensure increased accessibility of machinery to the stored products and ease of transit to their location of use. The operation of heavy construction equipment can cause damage to the neighboring buildings due to its strong vibrations, which can cause seismic movements (Ngoc et al. 2024). AIoT-powered drones can perform proximity analysis to evaluate the impact of heavy construction equipment on adjacent facilities and ensure safe construction practices are implemented. Setting up heavy construction equipment on-site is another challenge due to restricted accessibility and factors such as surrounding buildings and adjacent traffic (Ngoc et al. 2024). Drones enabled by AIoT can reveal optimal pathways for deploying such equipment, leading to improved on-site logistics and minimal disturbance to traffic and surrounding structures.

Therefore, AIoT-powered drones can enhance construction site layout by ensuring precise setup, optimizing equipment placement, reducing operational inefficiencies, predicting travel paths, and mitigating conflicts. They can also improve on-site logistics to conserve fuel, increase machinery accessibility, prevent damage to nearby structures, and streamline deployment, ultimately boosting productivity and safety on construction sites. Figure 7 displays a visual summary of the applications of AIoT-powered drones in this context.

3.2.3. Quality management and progress monitoring

Integrating AIoT with drones can significantly contribute to quality management on construction sites by enhancing and adding new dimensions to the existing methods of quality control. AIoT-powered drones can improve the inspection of construction works by combining high-resolution image capture with the computational capabilities of AI to detect

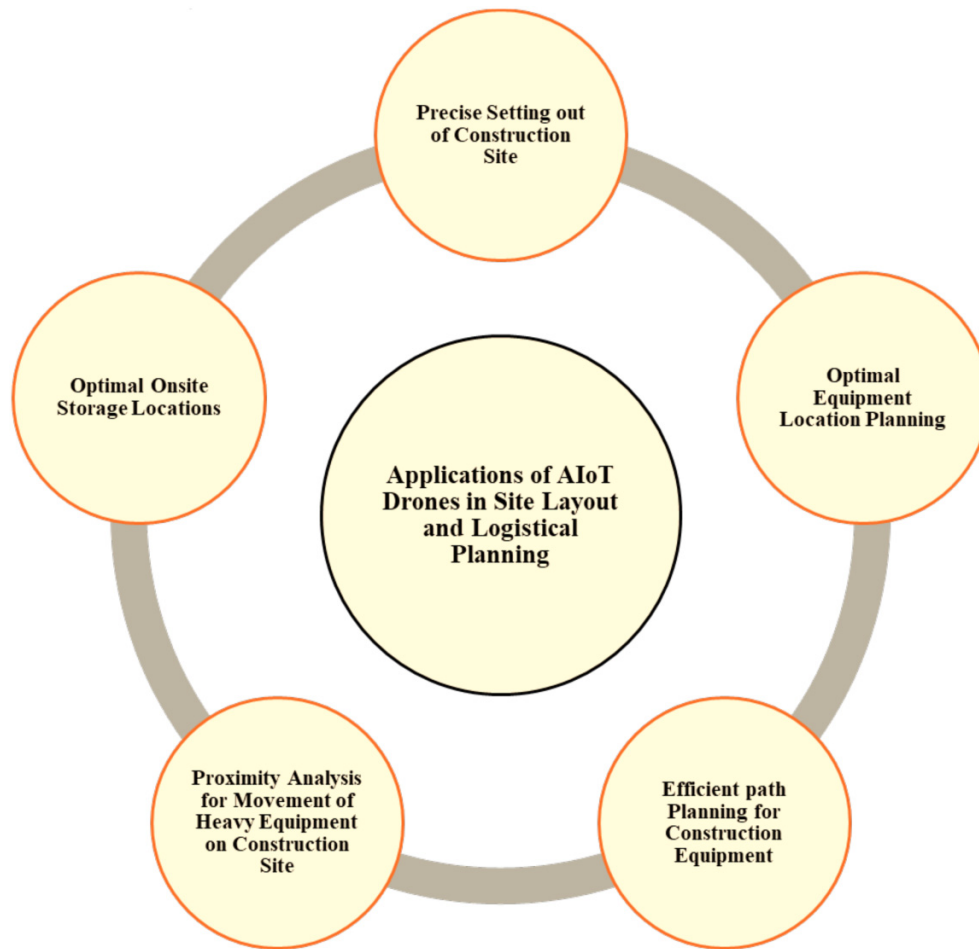
issues and defects in construction (Choi et al. 2024). Using thermal and LiDAR sensors, AIoT-powered drones can collect data on the temperature, water content, and other properties of concrete in building components, enabling construction managers to apply timely interventions for quality compliance (Alhassan et al. 2024). Detailed and high-resolution images provided by such drones can also enable the detection of minor defects, such as cracks, surface imperfections, and corrosion, that might otherwise be missed during regular inspections.

Moreover, AIoT-powered drones can collect data on weather conditions, such as humidity and surrounding temperature, while inspecting the slump of concrete, its temperature, and plasticity, allowing for appropriate changes in the mix design to be made for optimizing concrete quality and performance under varying environmental conditions (Salem et al. 2024). Another critical contribution of AIoT-powered drones in this regard is the early detection of deviations between the built components and planned ones, leading to a reduction in reworks, cost overruns, and time wastage. AIoT-powered drones can utilize digital twins to identify discrepancies between design specifications and construction progress, enabling timely actions to be taken to eliminate variances between planned and built facilities (Salem et al. 2024).

Another value added by AIoT-powered drones to quality control in construction projects is the automated and systematic documentation of construction progress and identified defects during inspections. AIoT-powered drones can identify and document any defects and issues that occur on a construction site, recording them in an online repository to increase transparency and accountability among stakeholders (Awaissi et al. 2024). Finally, by analyzing historical and real-time data from the construction site, AIoT-powered drones can identify potential quality issues that may arise on-site and provide actionable insights through data analytics.

Drones have found extensive applications in construction progress monitoring, and integrating AIoT in the process can create opportunities to expand their functionality and enhance their effectiveness. Through automated aerial imaging and photogrammetry surveys, AIoT-powered drones can continuously assess the status of construction activities, saving the time and effort required for traditional methods of construction progress monitoring performed manually. AIoT-powered drones can use point clouds to create detailed 3D models of the built structures and compare them with the planned models to quantify the amount of work done and the extent of the project completed (Choi et al. 2024). Consequently, the variances between the as-built and as-planned models can be identified and evaluated, ensuring precise tracking of construction progress and highlighting any deviations that require attention. Therefore, AIoT-powered drones can identify potential delays and bottlenecks more precisely than traditional means, allowing construction managers to take corrective measures to get projects back on schedule (Yildiz et al. 2021). This can also pave the way for visual documentation of the project, enabling stakeholders to understand the project's status better and fostering improved communication and coordination between project teams.

Fig. 7. Applications of AIoT-powered drones in construction site layout and logistical planning.



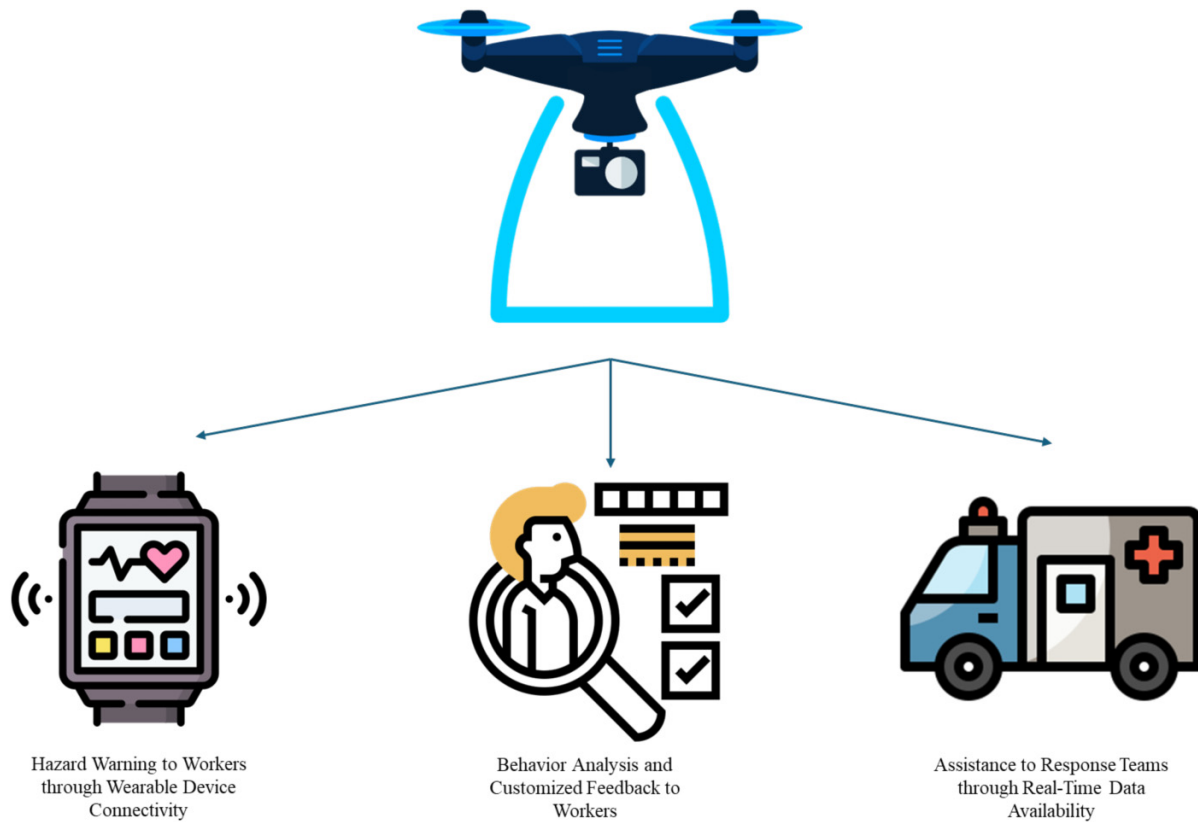
Using AIoT-powered drones, the productivity of construction activities can be calculated in real-time, allowing informed decision-making and resource allocation to enhance the productivity of construction works. Similarly, defective equipment can be identified based on low productivity, creating opportunities for timely maintenance and improving machinery efficiency (Yıldız et al. 2021). Automated and optimized scheduling of activities can also be achieved by leveraging detailed insights into construction progress, productivity, and resource utilization provided by AIoT-powered drones. They can also attain significance in delay analysis and preparation of claims by providing accurate data to all stakeholders, thereby increasing transparency and accountability (Ham et al. 2016). Consequently, disputes can be resolved more easily, and project timelines can be better managed, resulting in improved stakeholder relationships and enhanced project execution.

3.2.4. Safety management

Safety management at construction sites is a crucial aspect of construction management and successful project delivery. Drones can provide surveillance to safety managers, enabling them to identify hazardous working conditions and

scenarios. However, integrating AIoT with drones can further enhance safety management at construction sites by automating the identification of potential hazards, allowing for timely preventive measures to be taken for safe construction (Abioye et al. 2021). Hazardous site conditions, such as unstable structures, improper use of protective equipment, debris, and equipment malfunctions, can be identified through AIoT-powered drones, allowing construction managers to take necessary actions to ensure the safety of construction workers (Martinez et al. 2020). Similarly, AIoT-powered drones can be connected to wearable devices, allowing them to warn construction workers of specific hazards such as fall risks, compromised structures at risk of collapse, and proximity to working machinery (Chen et al. 2023). This can significantly reduce the number of accidents occurring on-site due to inattentive behavior by construction workers during activities. AIoT-powered drones can also take it a step further and analyze the behavior of different construction personnel, identify the hazard a worker is most likely to succumb to, and provide customized feedback to ensure the overall safety of each worker (Chen et al. 2023).

Drones can also contribute to emergency response teams in the event of an incident on the construction site. Through live video feeds, AIoT-powered drones can assess the situation by analyzing the affected area, access points, and probable res-

Fig. 8. Novel applications of AIoT-powered drones in safety management.

cue routes to assist in rescue operations. Using thermal sensors, missing personnel can be located, and hotspots in fire zones can also be detected (Kumaran et al. 2023). Real-time information provided by AIoT-powered drones can expedite emergency response efforts, enabling rescue teams to save lives and control emergencies. Moreover, the site maps prepared by AIoT-powered drones can assist the rescue teams in safely accessing specific sections of the construction site to carry out evacuations (Kumaran et al. 2023). In large-scale incidents, AIoT-powered drones can assist in monitoring and managing the flow of traffic to and from the construction site, ensuring that routes remain clear for emergency and rescue efforts. It also creates an opportunity for automated reporting of incidents by listing key findings and their implications, which can be leveraged to improve safety protocols on construction sites in the future (Iqbal et al. 2023). Figure 8 shows novel applications of AIoT-powered drones in construction safety management.

3.2.5. Construction site analytics and regulatory compliance

AIoT-powered drones can be a valuable tool for the continuous improvement of the construction process through advanced site analytics enabled by their data collection and computation. By identifying areas that require improvement and providing insights on measures to achieve this, AIoT-powered drones can enhance construction processes, result-

ing in increased productivity and improved overall project performance (Alahi et al. 2023). One of the primary ways for AIoT-powered drones to achieve this is by monitoring the operation of construction equipment and providing optimization strategies to increase their efficiency. This results in, the construction equipment will have reduced working hours, which can lead to fuel conservation and energy efficiency in construction works (Liang et al. 2023). Through image processing, AIoT-powered drones can identify different objects on construction sites that can hinder equipment's operational path, causing longer round trips and unnecessary fuel consumption. Thus, construction managers can remove such obstacles.

Another exciting opportunity created by AIoT-powered drones is real-time carbon accounting at construction sites. By monitoring material usage and energy consumption, the embodied emissions and operational emissions of a construction site can be quantified, allowing the concerned stakeholders to make informed decisions to minimize the carbon footprint of projects (Alhassan et al. 2024). Similarly, the construction and demolition waste generated at a construction site can be monitored through drones, ensuring its systematic sorting and storage in designated on-site spaces for the effective end-of-life management of construction projects. They can also analyze the effects of weather events to reveal the working conditions prevalent in the construction site, reporting their readiness for heavy construction works. This practice can also inform construction managers of specific steps

that must be taken to prepare the construction site for work, ensuring a safe working environment and satisfactory productivity (Larsson and Rudberg 2023).

Ensuring construction practices comply with regulatory standards is a critical aspect of successful project delivery. The enhanced surveillance provided by AIoT-powered drones can ensure that construction works comply with the prescribed standards, thereby aiding in the avoidance of legal penalties. By comparing the layout of a facility with established by-laws and local building codes for regulated land use, AIoT-powered drones can detect and prevent unlawful land use, such as encroachments (Agapiou 2020). This can help stakeholders avoid legal penalties and economic losses, ensure compliance with regulations, and promote orderly development. The management of construction and demolition waste is another challenging aspect of construction projects, as the traditional “take-make-use-dispose” approach often encourages landfilling of waste, leading to resource intensiveness and pollution (Dias et al. 2022).

AIoT-powered drones can be utilized to regulate the collection, sorting, and storage of construction and demolition waste, facilitating its recycling and reuse to promote a circular economy in the construction industry. Similarly, noise originating from construction works becomes a source of nuisance for the surrounding population (Agapiou 2020). By continuously measuring noise levels at construction sites, AIoT-powered drones enable construction managers to monitor noise pollution, promoting social sustainability at construction sites. Another contribution from AIoT-powered drones in this regard is monitoring water usage and discharge on construction sites to ensure the establishment of proper drainage systems and prevent the illegal discharge of affected water in nearby bodies of water (Sibanda et al. 2021). Lastly, AIoT-powered drones can monitor the working hours of laborers and construction practices to maintain compliance with labor laws and regulations (Kanan et al. 2018). Consequently, unsafe working conditions and excessive working hours for construction workers can be avoided, further enhancing the social sustainability of the construction sector.

3.2.6. Facility and asset management

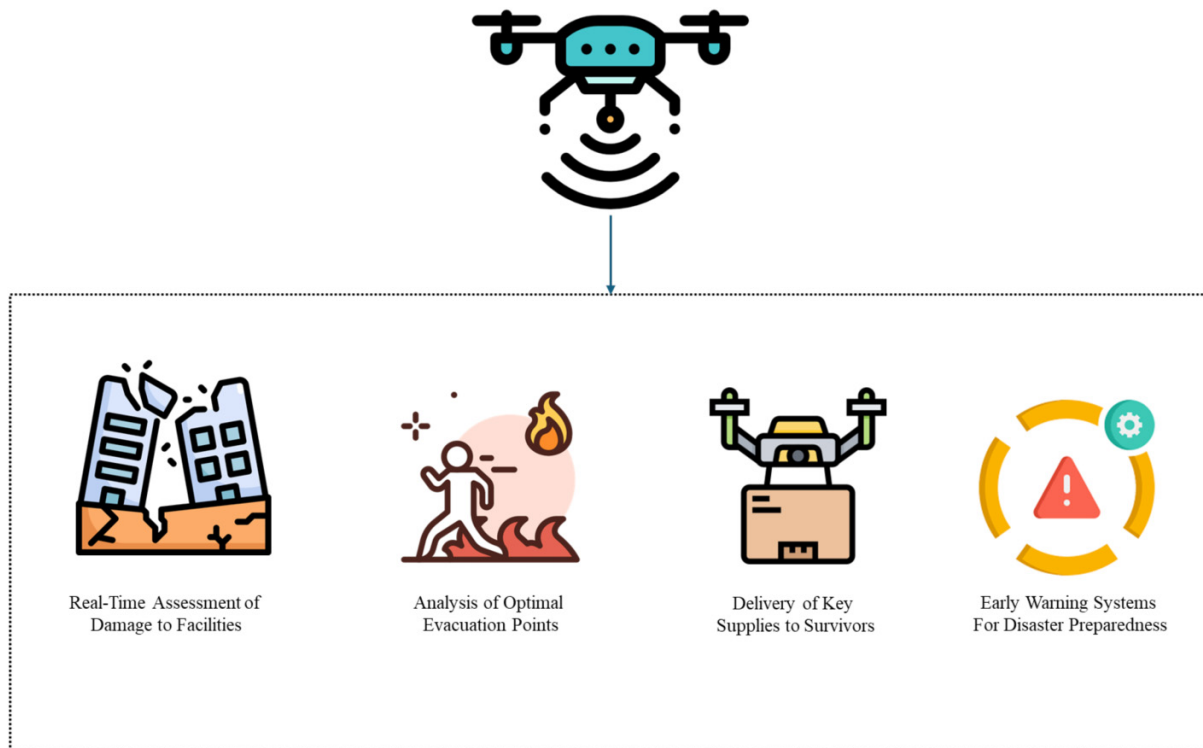
Drones have been extensively used in the field of asset and infrastructure management in recent years. Their use has increased significantly in infrastructure management, such as bridge maintenance. Integrating AIoT can further expand the range of drone applications in the realm of asset management and enhance their benefits as well. AIoT-powered drones can conduct regular inspections of facilities and infrastructure to assess their structural integrity and identify potential threats. Traditional methods of inspecting constructed facilities and asset management, such as bridges, involve on-site visits by personnel and evaluation of their condition based on expert judgment (Xu and Turkan 2020). Even the conventional use of drones requires the involvement of technical personnel to control the operation of drones and manually analyze data to make informed decisions, which hinders regular inspections of constructed facilities.

AIoT-powered drones, however, can automatically operate and conduct regular inspections of facilities to assess their structural integrity and report potential threats, such as cracks, at an earlier stage of building facility occupancy and operation.

In addition to enabling regular inspections of structures, AIoT-powered drones can enhance inspection processes, providing facility managers with detailed information to maintain structural integrity and perform timely facility maintenance (Fadhel et al. 2024). By integrating data from high-resolution imaging, LiDAR, and thermal sensors, AIoT-powered drones can provide deeper insights into the condition of structures and reveal minor cracks, moisture infiltration, and electrical faults. As a result, facility managers can apply timely interventions to ensure the safety and integrity of the constructed facilities. Inspection of structures, such as bridges and high-rise buildings, involves risk to the inspectors, as some regions of these structures are not easily accessible (Gao et al. 2023). This results in casualties and loss of life due to accidents. AIoT-powered drones can easily access such areas of the constructed facilities and provide relevant information to the facility managers regarding their condition and maintenance requirements. They can also be used to perform restoration and maintenance tasks by applying coatings and sealants to the identified cracks, thereby saving time and avoiding accidents in the process. This can also result in reducing the cost of maintenance, as performing maintenance tasks in inaccessible areas of structures often requires special equipment and arrangements, which can be avoided by using AIoT-powered drones for timely maintenance (Xu and Turkan 2020). Finally, the effects of natural events, such as earthquakes and typhoons, on infrastructure can be evaluated using AIoT-powered drones. These drones can perform non-destructive tests using thermal sensors, LiDAR, and acoustic sensors to report any defects in structures that may lead to collapse if left unattended (Yeom 2024). Achieving the same result with traditional means is comparatively complex, time-consuming, and expensive, which highlights the advantage of AIoT-powered drones.

3.2.7. Disaster management

AIoT-powered drones can be a critical asset in disaster planning and management. By providing high-resolution images and videos of the affected area, AIoT-powered drones can quickly survey the affected areas and assess the extent of damage to constructed facilities. This enables emergency teams to prioritize areas that require urgent attention and allocate additional resources accordingly. Another application of AIoT-powered drones in this regard is the real-time assessment of an affected area to unveil information regarding optimal evacuation points and emergency routes (Yang et al. 2021). By providing information about the evolving situation of an event to the respondents, they can enable respondents to make informed decisions, thereby increasing their chances of survival. AIoT-powered drones can be a valuable tool for search and rescue teams seeking to locate missing personnel following a disaster.

Fig. 9. Applications of Artificial Intelligence of Things-powered drones in disaster management.

Thermal sensors detect the heat signature of people who may be trapped under debris or in hard-to-reach areas, thereby increasing their chances of timely rescue (Ahmed 2024). Following a disaster such as a landslide, they can be used to perform terrain analysis and prepare 3D models of affected areas, indicating any changes in topography. The resulting maps and models can be insightful for emergency response efforts, rehabilitation of infrastructure, and prevention of future disasters (Bari et al. 2023). Delivering essential supplies to inaccessible areas in the event of forest fires and other disasters becomes a reality through AIoT-powered drones, which can locate survivors using image processing or heat signatures and automatically deliver medical kits, food, and water to them (Yeom 2024). Depending on the availability of resources, frequent use of AIoT-powered drones can help identify the abnormal trends of disaster-prone areas (flooding, earthquake zones, and typhoons) and contribute to early warning. This approach has been widely used in the military (Cheng et al. 2023).

By monitoring early indicators of natural disasters such as wind speeds, atmospheric temperature, and temperature changes, AIoT-powered drones can contribute to early warning systems, enabling communities to prepare and reducing the potential loss of life and infrastructure (Agbehadji et al. 2023). AIoT-powered drones can also prove beneficial for post-disaster recovery and rehabilitation efforts. They can be used to document and report on reconstruction efforts, ensuring that rebuilding efforts are on track. They can also identify if the rehabilitation efforts are falling behind and suggest some measures that can be taken to get them back on schedule (Yang et al. 2023).

Finally, AIoT-powered drones can assess environmental conditions following a disaster and investigate potential issues such as water contamination and hazardous material spills from constructed facilities. The information gathered on ecological conditions can be highly beneficial for ensuring public health and safety, as well as mitigating further environmental damage (Papayan et al. 2024). Figure 9 presents a visual summary of the application of AIoT-powered drones in disaster management.

4. Discussion

4.1. Key findings of the study

The study systematically reviewed the literature detailing the applications of AIoT-powered drones in the construction industry and revealed two key findings from the SLR.

1. AIoT can enhance the existing abilities of drones, making them more beneficial for the construction industry.
2. Integrating AIoT in drones can foster new opportunities and applications of drones in the construction industry.

Findings such as the improved inspection of constructed facilities to assess their structural integrity by combining data from high-resolution imaging point clouds constructed through LiDAR, acoustic sensors, and thermal sensors highlight the ability of AIoT-powered drones to build on the existing capabilities of drones. The automated construction of 2D and 3D ortho-mosaic maps by AIoT-powered drones, as well as the precise setting out of construction sites and their layout based on developed maps, are other findings

that strengthen the argument that integrating AIoT with drones can lead to improvements in their existing capabilities (Quamar et al. 2023).

A recurring challenge to the application of drones in the construction industry is the complex process of planning the flight path of drones, which is typically done manually by flight operators (Choi et al. 2023). Repeated use of drones becomes difficult due to the tedious process of flight path planning, which must be performed manually by the relevant personnel every time. AIoT-powered drones, on the other hand, can be programmed to automatically surveil the relevant areas and locations, thereby alleviating their excessive dependence on technical oversight for operation. However, there is still a need for a centralized control system to monitor the drones, as human intervention is essential in the event of a malfunction.

Another improvement of AIoT-powered drones over their predecessors is the real-time processing of data, which provides construction managers with actionable insights (Caballero-Martin et al. 2024). Previously, drones would gather data through aerial imaging and photogrammetry, which professionals would then process to draw valuable insights regarding certain issues. AIoT-powered drones can utilize ML and DL algorithms to identify problems and process data in real-time, providing actionable measures to construction managers and making the process less time-consuming and highly efficient (Choi et al. 2024).

The enhanced abilities of AIoT-powered drones are also evident in disaster management, where they can locate survivors through thermal sensing and image recognition, access hard-to-reach areas, and deliver essential supplies to survivors, thereby proving critical in saving lives. Previously, drones did not possess a higher level of automation, and tackling multiple tasks such as navigating flight paths, identifying survivors, and delivering goods proved much more complex (Kumaran et al. 2023).

In addition to enhancing the existing abilities of drones, integrating AIoT can create new applications for drones in the construction sector. For example, AIoT-powered drones can perform risk analysis on surveyed land to identify its vulnerability to landslides, soil erosion, and other hazards through slope and elevation analysis (Sun et al. 2024). Similarly, the effects of construction on its adjacent environment can be evaluated through EIA to identify the impact of activities such as land clearing on carbon sequestration. The optimal location of construction equipment, such as cranes, can be revealed by AIoT-powered drones based on construction site surveys, which can significantly enhance efficiency in construction work.

AIoT-powered drones can capture the progress of on-site activities and compare it with data from digital twins to reveal any deviations from plans and specifications, thereby reducing rework and leading to improved project execution, time, and cost savings (Salem et al. 2024). Similarly, AIoT-powered drones can be connected to wearable safety devices worn by construction workers to warn them of hazardous conditions, such as proximity to heavy construction equipment, improper handling of safety equipment, and potential falls (Khan et al. 2023). Moreover, they can monitor the activities

of each construction worker to reveal their tendencies and provide customized feedback for improving safety practices at construction sites (Rashidi et al. 2025).

The ability of AIoT-powered drones to generate big data creates opportunities for advanced site analytics, which can significantly enhance the productivity of construction operations, promote sustainability, and improve overall project management. They can also play a critical role in enhancing end-of-life management in construction projects by monitoring the collection, sorting, and storage of construction and demolition waste using the image recognition capabilities of AIoT-powered drones (Wang et al. 2024). This can significantly lower the landfilling of construction and demolition waste and contribute to reverse logistics in construction, presenting a novel contribution to the realm of construction and drone technology.

Similarly, compliance with land-use laws and regulations can be automated through AIoT-powered drones, building on the previously available applications of drones. The preparation of evacuation plans based on 3D models generated by drones and multiple simulations can reveal their effectiveness, making them instrumental in disaster preparedness and management (Kim et al. 2016). This can be achieved by integrating AIoT with drones. These findings support the notion that AIoT-powered drones can add new layers and applications to the existing uses of drones, thereby revamping the construction industry and contributing to its sustainable and swift development.

4.2. Implications of the study

The study holds both theoretical and practical implications for academia and construction industry practitioners. Theoretically, the study investigates and establishes the applications of AIoT-powered drones in the construction industry, focusing on the enhancements that AIoT-powered drones can bring to existing drone applications. Moreover, the study identifies new applications of drones that can be created through the integration of AIoT with drones, adding to the body of knowledge regarding AIoT-powered drones in construction.

Previous review studies have identified opportunities and benefits of employing drones in the construction industry. However, the literature on the impact of integrating AIoT technology in drones and its implications for the built environment was scarce, presenting a notable gap that the current study aimed to address by systematically reviewing the effects of employing AIoT-powered drones in the construction sector.

The current study paves the path for future researchers to rigorously investigate this research theme by highlighting the immense potential of AIoT-powered drones for revolutionizing the construction industry. The study also serves as a guide for future research targeted at individual areas of application for AIoT-powered drones, which can be published as standalone studies in the future. By addressing a neglected area of the literature regarding drones and AIoT, the study not only consolidates the body of knowledge regarding the potential applications of AIoT-powered drones in

the construction industry but also paves the path for future researchers to explore innovative uses, develop advanced methodologies, and identify new areas of impact within the field. Each highlighted area can be further investigated by future researchers.

The study holds practical significance as it seeks to expedite the adoption of AIoT-powered drones in the construction industry by highlighting their benefits to key stakeholders. The diverse applications of AIoT-powered drones detailed in the study are meant to highlight the ability of AIoT-powered drones to reshape construction practices, enabling higher productivity, safety, economic turnover, and efficiency. By documenting and reporting these benefits to the readers and stakeholders, the study aims to accelerate the adoption and use of AIoT-powered drones in mainstream construction. Another practical implication of the study is the improvement of construction practices by encouraging the use of AIoT-powered drones. By educating stakeholders about the applications of their products across various stages of a construction project and their benefits, the study aims to enhance overall project performance.

The study presents a picture of the future of the construction industry in the face of the AI revolution, enabling organizations to anticipate the industry's trajectory and develop strategic plans to embrace the change. Consequently, practitioners can utilize these insights to develop customized regulations and policies for integrating AIoT-powered drones in construction firms, ensuring a thorough and holistic adoption across the construction sector.

The study can also contribute to the attainment of UN SDGs by facilitating the adoption of AIoT-powered drones in mainstream construction (Shooshtarian et al. 2022). For example, the diverse applications of AIoT-powered drones in land use planning and the preservation of the natural environment demonstrate their ability to contribute to UN SDG-11, specifically "Sustainable Cities and Communities" (Sharifi et al. 2024). By encouraging the reverse logistics of construction and demolition waste, AIoT-powered drones can foster circularity in the resource loops of the construction industry, thereby contributing to UN SDG-12, which addresses "Responsible Production and Consumption" (Sajid et al. 2024). By shedding light on the values generated by AIoT-powered drones in the construction industry, the current study aims to encourage the adoption of AIoT-powered drones in construction, highlighting their practical implications.

4.3. Challenges and future directions

Despite the numerous contributions that AIoT-powered drones make to the construction sector, there are certain impediments and challenges to their widespread adoption. The first is a lack of technical understanding and knowledge among practitioners regarding the use of AIoT-powered drones. Moreover, due to the nascent nature of the technology, the benefits of AIoT-powered drones in the global construction industry are not well understood. The resistance to change prevalent in the construction industry is another challenge that hinders the rapid adoption of AIoT-powered drones, like other emerging technologies. The lack of success-

ful precedents in the construction sector regarding the use of AIoT-powered drones is another factor that prompts hesitation among stakeholders to adopt this technology quickly. High upfront costs in acquiring such technology and training organizations to utilize it are other key considerations that contribute to the stagnant adoption of AI and its various facets in the mainstream construction sector. Frameworks outlining integrated approaches to leverage AIoT-powered drones across different stages of development are also lacking, which creates knowledge gaps regarding the technology and its application.

Consequently, a lack of guidelines is observed regarding the use of AIoT-powered drones, which causes stakeholders to delay their immediate transition to the technology. Finally, there are ethical concerns related to the use of AIoT-powered drones, as they can gather large amounts of information through aerial imaging during asset inventory preparation. While doing so, they can result in the invasion of the privacy of the residents of neighboring facilities, presenting cybersecurity and ethical concerns for the relevant stakeholders.

Future work should rigorously investigate the individual applications of AIoT-powered drones in depth and compare them with existing methodologies to highlight prospects for improving the construction process. Awareness campaigns should be conducted to disseminate knowledge about the advantages of AIoT-powered drones for the construction industry, thereby accelerating their adoption. Technical knowledge and skills should be transferred to personnel from organizations worldwide to facilitate their application in construction projects. Researchers should focus on identifying the barriers to the adoption of AIoT-powered drones in the construction industry and devise solutions to mitigate these obstacles. Future studies should devise frameworks to integrate AIoT-powered drones with conventional construction management practices and propose guidelines for their effective use across different stages of a constructed facility's lifecycle. By taking a multifaceted approach that involves governing bodies, industry practitioners, academicians, and organizations, the construction industry can harness the potential of AIoT-powered drones to enhance construction processes and pave the way for sustainable development in the built environment.

5. Conclusion

Against the backdrop of digitalization and the industrial revolution in the construction sector, disruptive technologies such as AIoT and drones have gained significance in recent years. The current study aims to contribute to the ongoing discourse by investigating the applications of AIoT-enabled drones in the construction sector. By conducting a bibliometric analysis, the study reveals an upward trend in the literature regarding research into the applications of AIoT and drones, with 2023 reporting the highest number of publications (40). The growing interest from developing countries, such as India (41 publications), and developed countries, like the USA (26) and China (20), indicates the global significance of the research theme. The study also

conducts a content analysis to identify potential areas of application for AIoT-powered drones, as well as their contributions to enhancing previous drone applications in the built environment.

The study reveals that AIoT-powered drones can prove to be instrumental in reshaping the construction sector by contributing to (1) land surveying and site selection, (2) site layout and logistical planning, (3) quality management and progress monitoring, (4) safety management, (5) construction site analytics and regulatory compliance, (6) facility and asset management, and (7) disaster management. Detailed discourse on each aspect reveals two recurring findings regarding the application of AIoT-powered drones in construction, which indicate that AIoT-powered drones can enhance existing applications of drones such as land surveying, inspection of defects in construction works, and threats identification to the structural integrity of structural members by leveraging the big data analytics and computational prowess of the AI and IoT technology. It can also create new areas of application for drones, such as monitoring the behavior of construction workers to improve safe construction practices, real-time carbon accounting, site layout optimization, and automated construction progress monitoring, which had not been fully realized in their potential before AIoT technology.

The study is limited in terms of the number of repositories used for extracting the relevant literature, as only Scopus and WoS were used. Future works can incorporate more databases to retrieve the relevant literature and conduct a more comprehensive exploration of the research theme. Another limitation of the study is that there are limited articles with an exclusive focus on the applications of AIoT and drones in the construction industry, as the research theme is still in its early stages of development. As the research theme matures with additional publications in the future, subsequent studies may reveal more insightful findings that differ from those presented in the current study. Future research can focus on delineating pathways to integrate the use of AIoT-powered drones with conventional stages of construction projects, thereby facilitating their adoption in the construction sector. Individual applications of AIoT-powered drones should also be scrutinized to draw deeper insights into the research topic.

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Data availability

Data generated or analyzed during this study are provided in full within the published article and its [Appendix A](#).

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Appendix A

Table A1. Studies included in the review.

ID	Title	Author	Year	Journal
1	A Neural Computing-Based Access Control Protocol for AI-Driven Intelligent Flying Vehicles in Industry 5.0-Assisted Consumer Electronics	Mahmood K.; Tariq T.; Sangaiah A.K.; Ghaffar Z.; Saleem M.A.; Shamshad S.	2024	IEEE Transactions on Consumer Electronics
2	Artificial intelligence-enabled Internet of Things-based system for COVID-19 screening using aerial thermal imaging.	Barnawi A.; Chhikara P.; Tekchandani R.; Kumar N.; Alzahrani B.	2021	Future Generation Computer Systems
3	Intelligent Blockchain-Enabled Communication and Services: Solutions for Moving Internet of Things Devices	Ridhawi I.A.; Aloqaily M.; Karray F.	2022	IEEE Robotics and Automation Magazine
4	Digital technologies as enablers of supply chain sustainability in an emerging economy	Akbari M.; Hopkins J.L.	2022	Operations Management Research
5	Building Integrated Photovoltaics 4.0: Digitization of the Photovoltaic Integration in Buildings for a Resilient Infra at Large Scale	Singh D.; Akram S.V.; Singh R.; Gehlot A.; Buddhi D.; Priyadarshi N.; Sharma G.; Bokoro P.N.	2022	Electronics (Switzerland)
6	An Overview of State-of-the-Art Technologies for Data-Driven Construction	Woo J.; Shin S.; Asutosh A.T.; Li J.; Kibert C.J.	2021	Lecture Notes in Civil Engineering
7	Effect of the Fourth Industrial Revolution on Road Transport Asset Management Practice in Nigeria	Gambo N.; Musonda I.	2021	Journal of Construction in Developing Countries
8	Leveraging precision agriculture techniques using UAVs and emerging disruptive technologies	Raj M.; N B H.; Gupta S.; Atiquzzaman M.; Rawlley O.; Goel L.	2024	Energy Nexus
9	A Model for Infrastructure Detection along Highways Based on Remote Sensing Images from UAVs	Jiang X.; Cui Q.; Wang C.; Wang F.; Zhao Y.; Hou Y.; Zhuang R.; Mei Y.; Shi G.	2023	Sensors
10	Shipping in the era of digitalization: Mapping the future strategic plans of major maritime commercial actors	Ichimura Y.; Dalaklis D.; Kitada M.; Christodoulou A.	2022	Digital Business
11	IoT Enabled Technologies in Smart Farming and Challenges for Adoption	Kumar R.; Sinwar D.; Pandey A.; Tadele T.; Singh V.; Raghuvanshi G.	2021	Studies in Big Data
12	Developing Deep Learning Based Change Detection Model for Breakwaters Observed by UAV (Unmanned Aerial Vehicle)	Ni Putu Praja C.; Jeon G.-S.; Baek S.	2022	Journal of the Korean Society of Surveying, Geodesy, Photogrammetry and Cartography
13	Multi-hazard disaster studies: Monitoring, detection, recovery, and management, based on emerging technologies and optimal techniques	Khan A.; Gupta S.; Gupta S.K.	2020	International Journal of Disaster Risk Reduction
14	Sustainable Urban Freight for Energy-Efficient Smart Cities–Systematic Literature Review	Golinska-Dawson P.; Sethanan K.	2023	Energies
15	Sensors and healthcare 5.0: transformative shift in virtual care through emerging digital health technologies	Mbunge E.; Muchemwa B.; Jiyane S.; Batani J.	2021	Global Health Journal
16	GA-DCTSP: An Intelligent Active Data Processing Scheme for UAV-Enabled Edge Computing	Bai J.; Huang G.; Zhang S.; Zeng Z.; Liu A.	2023	IEEE Internet of Things Journal
17	Sustainable Smart Cities: Enabling Technologies, Energy Trends and Potential Applications	Mishra P.; Singh G.	2023	Sustainable Cities and Society
18	Function orientation and typical application scenarios of the Internet of Things construction for power transmission and transformation equipment	Wu C.; Jia P.; Yu X.; Guan J.; Deng J.; Cheng H.	2022	Energy Reports
19	A bibliometric analysis of digital technologies use in construction health and safety	Dobrucali E.; Sadikoglu E.; Demirkesen S.; Zhang C.; Tezel A.; Kiral I.A.	2023	Engineering, Construction and Architectural Management

Table A1. (concluded).

ID	Title	Author	Year	Journal
20	The Application of Geospatial Artificial Intelligence, Geo Internet of Things and Geostatistical Visual Analytics for Urban Recovery Planning and Management Due to the Eruption of Mount Semeru, Indonesia	Yudono A.; Santosa H.; Maryanto S.; Sujarwo; Nurjannah; Rahatiningtyas N.S.; Shalih O.	2023	Springer Geography
21	AI for UAV-Assisted IoT Applications: A Comprehensive Review	Cheng N.; Wu S.; Wang X.; Yin Z.; Li C.; Chen W.; Chen F.	2023	IEEE Internet of Things Journal
22	Recent Trends in Internet-of-Things-Enabled Sensor Technologies for Smart Agriculture	Shaikh F.K.; Karim S.; Zeadally S.; Nebhen J.	2022	IEEE Internet of Things Journal
23	Development of Smart Mobility Infrastructure in Saudi Arabia: A Benchmarking Approach	Alanazi F.	2023	Sustainability
24	Visual image design of the internet of things based on AI intelligence	Tian, T	2023	Heliyon
25	Heterogeneous Flight Management System (FMS) Design for Unmanned Aerial Vehicles (UAVs): Current Stages, Challenges, and Opportunities	Wang, GL; Gu, CY; Li, J; Wang, JQ; Chen, XM; Zhang, H	2023	Drones
26	Planning the Future of Smart Cities With Swarms of Fully Autonomous Unmanned Aerial Vehicles Using a Novel Framework	Kuru, K	2021	IEEE Access
27	Digital twin-enabled domain adaptation for zero-touch UAV networks: Survey and challenges	McManus, M; Cui, YQ; Zhang, J; Hu, JQ; Moorthy, SK; Mastronarde, N; Bentley, ES; Medley, M; Guan, ZY	2023	Computer Networks
28	Adversarial Attacks and Defenses Toward AI-Assisted UAV Infrastructure Inspection	Raja, A; Njilla, L; Yuan, JW	2022	IEEE Internet of Things
29	UAVs joint optimization problems and machine learning to improve the 5 G and Beyond communication	Ullah Z.; Al-Turjman F.; Moatasim U.; Mostarda L.; Gagliardi R.	2020	Computer Networks
30	Smart Campus 4.0: Digitalization of University Campus with Assimilation of Industry 4.0 for Innovation and Sustainability	Mahariya S.K.; Kumar A.; Singh R.; Gehlot A.; Akram S.V.; Twala B.; Iqbal M.I.; Priyadarshi N.	2023	Journal of Advanced Research in Applied Sciences and Engineering Technology
31	Integration of Smart Pavement Data with Decision Support Systems: A Systematic Review	Budak I., Radeka M.	2021	Buildings