

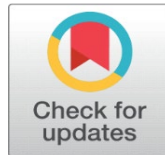
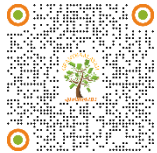
APPLICATIONS OF DRONE TECHNOLOGY IN CONSTRUCTION PROJECTS: A SYSTEMATIC LITERATURE REVIEW

Nitha Mary¹✉, Syeeda Shafiya²✉, Maroua Ben Maaouia³✉

¹Senior Lecturer, Muscat College, Oman

²Deputy Head of Business and Accounting, Muscat College, Oman

³Assistant Professor, Muscat College, Oman



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Corresponding Author

Maroua Ben Maaouia,
maroua.maaouia@muscatcollege.edu.om

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ABSTRACT

Drone technology has evaded various sectors, among which Construction is a prominent one. The communication between stakeholders can be improved using Drone technology. Furthermore, the use of drone technology will help them to accomplish the project on time and on budget. This paper aims to study the potential of the utilization of drones in the construction industry and extend it to understand the benefits and impacts of drones as a new trend. This is a review article based on SPAR4 SLR Methodology to analyze the existing knowledge in this field and explore the effects of Drones' usage in the construction industry. Furthermore, the article has explored the benefits of using drones in construction by considering it as a project-related sector. Various dimensions of Project Management have been considered in analyzing the benefits of using Drone Technology.

Keywords: Drone Technology, Project Management, Construction Sector, Projects Performance

1. INTRODUCTION

A construction project can be defined as a multi-organizational company, unique, temporary, and subject to the problem of delivery to a specific site where several partners must be mobilized for a given period [Elghaish et al. \(2021\)](#). Other phenomena add to these characteristics and often contribute to the complexity of projects: client needs that are sometimes imprecise and changing, causing significant change costs; little overall learning because of few repetitions; high risks

due to novelty; technical, climatic and even societal uncertainties; coordination and complex decision-making processes between the teams involved; changing conditions of realization; etc. [De Blois et al. \(2016\)](#). The construction sector is also characterized by a high fragmentation of the entire value chain to which many stakeholders contribute. In addition to the clients, there are teachers.

Although the data indicate a delay in the construction sector in adopting advanced technologies [Albeaino et al. \(2019\)](#), McKinsey Institute analysis indicates that Construction is one of the least digitized sectors. Several ongoing initiatives suggest a gradual change in practices in this industry, often considered traditional [Mahajan \(2021\)](#). This change is driven by a concern to be in line with the innovations observed at the international level and to respond to important national challenges: workforce, competitiveness, sustainable development, etc. Digital transformation is one of the preferred avenues to improve the sector's overall performance over the long term [Deloitte \(2019\)](#). This digital transformation is expressed in different ways. One of the strong currents is based on the so-called concept of the fourth industrial revolution based on drone technology utilisation.

This trend can be defined as the transition from a realization and management centred on static sources of information (e.g. plans and paper specifications) to completion and management based on a source of information grouped and reusable for various purposes [Poirier et al. \(2018\)](#). In the construction sector, the digital transformation, therefore, aims to allow faster and more extensive access to information to increase the added value at the different links in the value chain [Roca et al. \(2013\)](#).

Drones quickly proved their efficiencies in the construction industry. This sector is one of the significant contributors to the country's economy, and the industry must adopt emerging technologies to effectively manage construction projects and improve productivity and the value chain [Golizadeh et al. \(2019\)](#). It is suggested by the Associated General Contractors of America (ACG) that UAVs can document the projects' progress, providing a visual record capable of reducing the later disputes between contractors and landowners; it can be eventually used to carry tools and equipment from one location to another.

2. LITERATURE REVIEW

2.1. DEPLOYMENT OF DRONE TECHNOLOGY IN THE CONSTRUCTION INDUSTRY

Digital technologies are being researched for various applications, including procurement [Ibem and Laryea \(2014\)](#), participation in major construction projects, construction safety and productivity enhancement [Ibrahim \(2013\)](#). Numerous different studies concentrate on specialized technologies like sensors and the Internet of Things (IoT) [Woodhead et al. \(2018\)](#), construction robotics unmanned aerial vehicles (UAV) or drones [Albeaino et al. \(2019\)](#), fully interactive, significantly improved, and mixed realities [Martinez et al. \(2020\)](#). Since the increasing penetration of drones on the workplace only a few years ago, the construction sector has experienced significant changes and advances. Substantial improvements have been made to improve various procedures on a construction project, altering how we approach project implementation. Site monitoring, which encompasses responsibilities ranging from aerial photography to inspections and tracking, has been one of the most notable applications of drones in Construction [Yoo \(2021\)](#).

Every year, the number of cases of using drone technology in building designs grows. The brand-new approaches for characterizing drones during flight became

the most important significant part [Devers et al. \(2019\)](#). With these technologies, building companies may handle the information collected by their drones to demonstrate techniques and provide features for construction management related to Estimation, Survey, Performance Monitoring, Site Monitoring, Quality Assurance, and Safety Organizational reports. Drones are an innovative technology with enormous opportunities to transform future and existing construction industry demands and practices, offering amazing cost, time, industrial perspective for managers, and construction quality advantages over traditional approaches [16]. In the construction industry, aerial vehicles have been practiced inspecting expressways, flyovers, road systems, cell towers, greater mast bright lights, wind turbines, power transmission lines, building façade and roof, survey and geo-referencing, construction monitoring, wetland/environmental, drainage and erosion, traffic monitoring, and emergency services etc. are a handful of examples [Motavwa and Kardakou \(2018\)](#). Construction drones offer builders an unmatched perspective of a site at a relatively lower price, facilitating them to track problems, follow developments, and create better plans on the spot. This mostly relates to labor, material waste, site inspection, and total return on investment in construction projects (ROI) [Sawant et al. \(2021\)](#). 3D surveying, 3D designs, 3D ICT construction, and 3D inspection are the foundations of intelligent Construction, which is focused on future building technologies in several nations.

Drones supply helpful information, including 3D point cloud modelling, ecosystem function, and asset inventory tracking for the building industry [Poikonen and Campbell \(2021\)](#). According to research by McKinsey issued in 2020, disintegration will eventually become the new normal. The COVID-19 crisis hastens large-scale transformation, which has already commenced. According to McKinsey's analysis, the sector might seem a little prominent in five to ten years. A recent study has described how the Covid-19 pandemic affects project performance in CI [Sami Ur Rehman et al. \(2022\)](#). Researchers also explained how to use DT to manage disasters and risks related to the pandemic in the construction industry [Zhou and Gheisari \(2018\)](#). A recent study focused on the future directions of drone routing research, and the findings of this research have been used in many drone applications utilizing various models and kinds [Husien et al. \(2021\)](#). In a scenario with a labor scarcity, it is essential to discover strategies to enhance construction sites' efficiency and lower the necessary labor force.

2.2. ADOPTION OF DRONE IN OTHER SECTORS

Furthermore, because drones are not affected by weather, these drones for irrigation are more cost-effective than satellites [Yoo \(2021\)](#). It has been shown that using drones to transport medical supplies is advantageous for the healthcare industry. Drugs and diagnostic kits for chronic illnesses can be distributed and picked up by drones [Kim et al. \(2017\)](#). Defense groups and technologically capable individuals have been using drone technology for a while. Many of the most hazardous and lucrative occupations in the business sector are ready to be replaced by drone technology as their accessibility increases [Lee et al. \(2020\)](#).

3. SYSTEMATIC REVIEW OF THE RESEARCH IN THE FIELD

The article explores the trends in the application of drone technology in Construction. A systematic Literature Review has been employed in the current study. A well-planned review is used to answer research questions in a Systematic Literature Review. The studies' identification, selection, and evaluation are made

using a systematic and explicit methodology in the Systematic Literature Review [Paul et al. \(2021\)](#). The current study focuses on a domain-based review using a Bibliometric review to analyse the results [Paul et al. \(2021\)](#). Systematic Procedures and Rationales for Systematic Literature Review (SPAR 4 SLR) Model has been used as a review protocol. There are three main stages in the SPAR 4 SLR Model. The research questions could be defined as below: [Figure 1](#)

RQ1. What are the research trends in the application of drone technology in Construction?

RQ2: Benefits of using Drone in Construction Projects?

RQ3: Barriers in using Drones in Construction Projects?

Figure 1

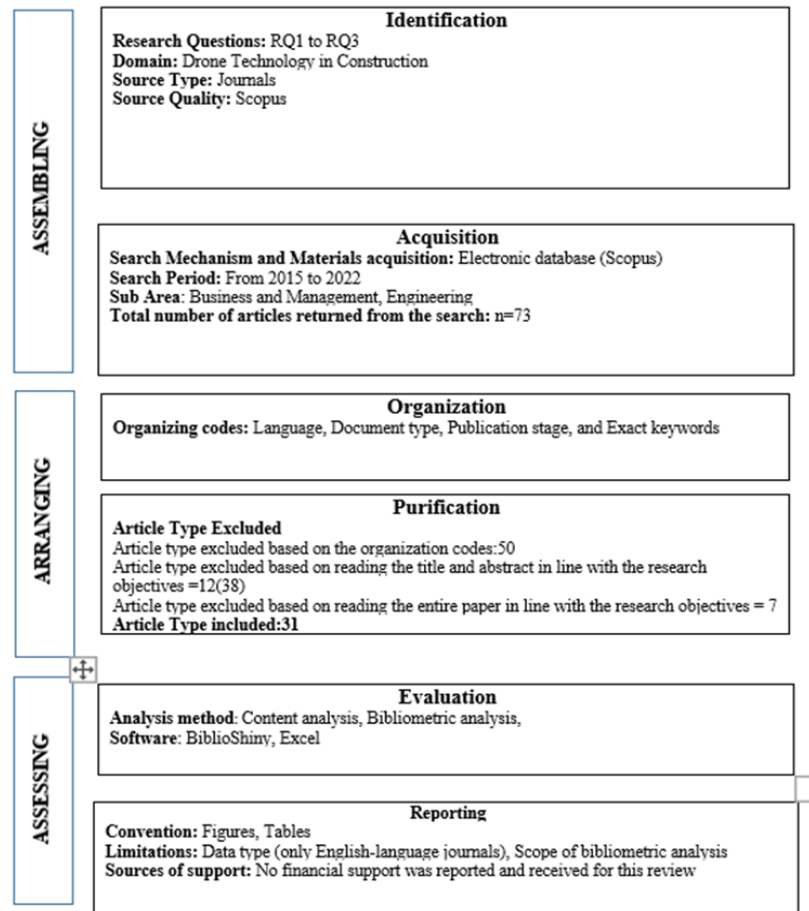


Figure (1): Implementation of Systematic Literature Review in the current study according to SPAR-4-SLR Protocol (Paul et al., 2021)

Figure 1 Implementation of Systematic Literature Review according to SPAR-4-SLR Protocol

The first stage is assembling, where relevant literature is identified and acquired in the study domain. In the identification stage, the articles on the theme "Drone Technology in Construction" were searched from Scopus. The source type is set as Journal Publications. The relevant materials have been acquired in the second substage of Assembling, which is the acquisition stage. The search words are set at: "drone AND technology AND in AND construction" for the title, abstract and keywords which generate around 302 documents. 2015 to 2022 has been set as the

publication year as the domain deals with ever-changing technology. The sub-areas have been set as Business, Management and Accounting and Engineering. Hence the search terms have been further refined to TITLE-ABS-KEY (drone AND technology AND in AND Construction).

Seventy-three documents have been carried forward to the second stage of Arranging. Organization of articles is the first substage in arranging. Language, Type of document, publication stage and exact keywords were used in this stage as codes for organizing. These are done as per the guidelines proposed by [Paul et al. \(2021\)](#). The purification is the second sub-stage in the arranging phase, where the inclusion and exclusion criteria are mentioned. The inclusion criteria depend on the above organization codes. English is selected as the language of the selected articles considering the proficiency of the researcher." Article" is considered for document type, and the publication stage is set as "Final". The exact keywords have been further set based on the objectives of the study. TITLE-ABS-KEY (drone AND technology AND in AND construction) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015)) AND (LIMIT-TO (EXACTKEYWORD , "Drones") OR LIMIT-TO (EXACTKEYWORD , "Antennas") OR LIMIT-TO (EXACTKEYWORD , "ConstructionIndustry") OR LIMIT-TO (EXACTKEYWORD , "Drone")).

Around 50 articles were filtered based on the inclusion criteria as per the organization codes. Further purification has been done by filtering the articles based on the researchers' analysis of the abstract and title, which further screened the articles to 38. The total inclusion has been set at 31 after reading the full articles. According to [Paul et al. \(2021\)](#), the refined literature in the arranging stage is evaluated and reported in the assessing stage. As mentioned earlier, the analysis is done using a Bibliometric review.

4. RESEARCH TRENDS

Bibliometric analysis is used to analyse research trends in drone technology in Construction. Performance analysis analyses the publication trend, Top Countries, Top articles, and Top authors. Similarly, Science Mapping analyses the authors' country collaboration and Co-occurrence analysis. Bibliometric analysis has been done using Microsoft Excel, Biblioshiny and Vos Viewer. [Table 1](#)

Table 1

Table 1 Publication Trend of Articles in the Domain "Drones in Construction"

Year	N
2016	1
2017	1
2018	4
2019	5
2020	4
2021	11
2022	4

The publication trend of the articles in drones in Construction can be identified in Table 1 and Figure 2. It is noteworthy that the publication trend has shown an amazing hike since 2018. In 2021 the number of articles published in the domain of study had reached 11. By June 2022, the number of articles published has reached 4. Hence it can be inferred that the researchers are investigating various aspects of the use of drones in Construction.

Figure 2

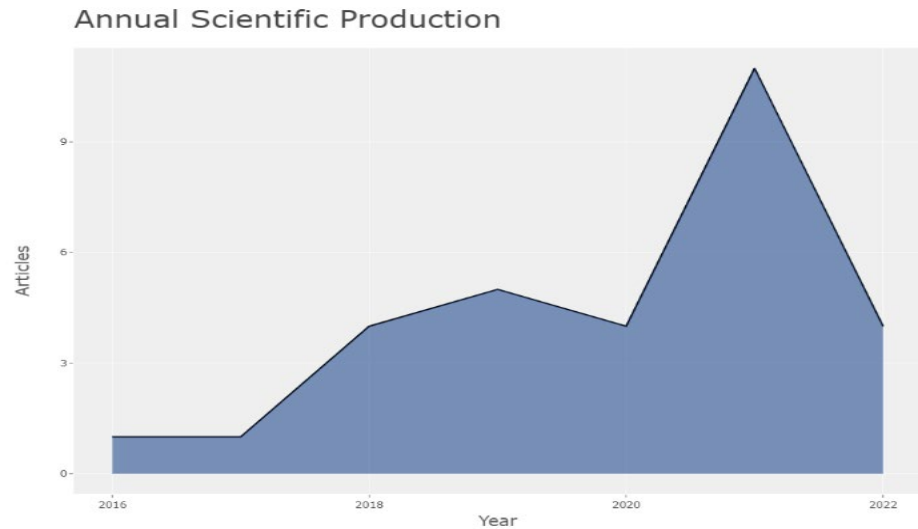


Figure 2 Publication Trend of Articles in the Domain "Drones in Construction" Derived from Biblioshiny

Local and Global citations are used to analyse the top articles in the domain of the study. From Table 2, it can be identified that the article titled "Applications of multirotor drone technologies in construction management" authored by Li Y., Liu C. has received a global citation of 88, followed by "What are the prospects for robots in the construction industry?" authored by Bogue with a global citation of 66. The number of global citations indicates the topic's wide acceptance and importance in academic research. The First article receives five local citations. However, the number of local citations is comparatively low, which reminds the researchers of the importance of local citation analysis.

This table indicates the Top authors in the area of study. Abrishami and Hosseini are the top authors with two articles in "Drones in Construction". The remaining authors have only a single article published related to the domain of study. The low number of articles published by the authors specialized in the domain indicated that there are still opportunities for researchers to explore and publish journal articles in the domain in high-quality journals.

Table 2

Table 2 Top Authors in the domain "Drones in Construction"

Authors	Articles
ABRISHAMI S	2
HOSSEINI MR	2
AGAPIOU A	1
AL-HAMDANI S	1

ALBEAINO G	1
ALSAMARRAIE M	1
AWANGHAMAT MA	1
BANIHASHEMI S	1
BAYLIS B	1
BEHZADAN AH	1
BOGUE R	1
BOSCH-SIJTSEMA P	1
BRANCHE CM	1
CASTRILLO VU	1
CHA JS	1
CHASPARI T	1
CHONG HY	1
CLAESON-JONSSON C	1
CONLY JM	1
CRUDEN AR	1

The Journals that publish the maximum number of articles in the domain selected for study are included in [Table 3](#). Construction Innovation, IEEE Access and Mobile Information Systems have two articles in the study area. Journal of Construction Management has an h index and G-index 2. The remaining journals listed in the table have only one article, each published in the area of "drones in Construction."

Table 3

Table 3 Top journals in the domain "Drones in Construction"						
Source	h_index	g_index	m_index	TC	NP	PY_start
CONSTRUCTION INNOVATION	2	2	0.5	34	2	2019
IEEE ACCESS	1	2	0.333333	5	2	2020
MOBILE INFORMATION SYSTEMS	1	2	0.2	8	2	2018
AMERICAN JOURNAL OF INDUSTRIAL MEDICINE	1	1	0.2	25	1	2018
APPLIED SCIENCES (SWITZERLAND)	1	1	0.5	3	1	2021
CIGRE SCIENCE AND ENGINEERING	0	0	0	0	1	2021
DRONES	1	1	1	1	1	2022
EASTERN-EUROPEAN JOURNAL OF ENTERPRISE TECHNOLOGIES	1	1	0.25	1	1	2019
ENGINEERING, CONSTRUCTION AND	1	1	0.5	3	1	2021

ARCHITECTURAL MANAGEMENT							
INDUSTRIAL ROBOT	1	1	0.2	60	1	2018	
INTERNATIONAL JOURNAL OF CIVIL ENGINEERING	1	1	1	2	1	2022	
INTERNATIONAL JOURNAL OF CONSTRUCTION MANAGEMENT	1	1	0.25	88	1	2019	
INTERNATIONAL JOURNAL OF INNOVATIVE TECHNOLOGY AND EXPLORING ENGINEERING	1	1	0.25	3	1	2019	
JOURNAL OF COMPUTING IN CIVIL ENGINEERING	1	1	0.5	6	1	2021	
JOURNAL OF DIGITAL IMAGING	1	1	0.5	1	1	2021	
JOURNAL OF INFORMATION TECHNOLOGY IN CONSTRUCTION	1	1	0.5	5	1	2021	
JOURNAL OF MANAGEMENT IN ENGINEERING	1	1	0.2	18	1	2018	

From Figure 3, it can be concluded that the articles are all centred on the central theme of drone technology from where the three other clusters are linked.

Figure 3

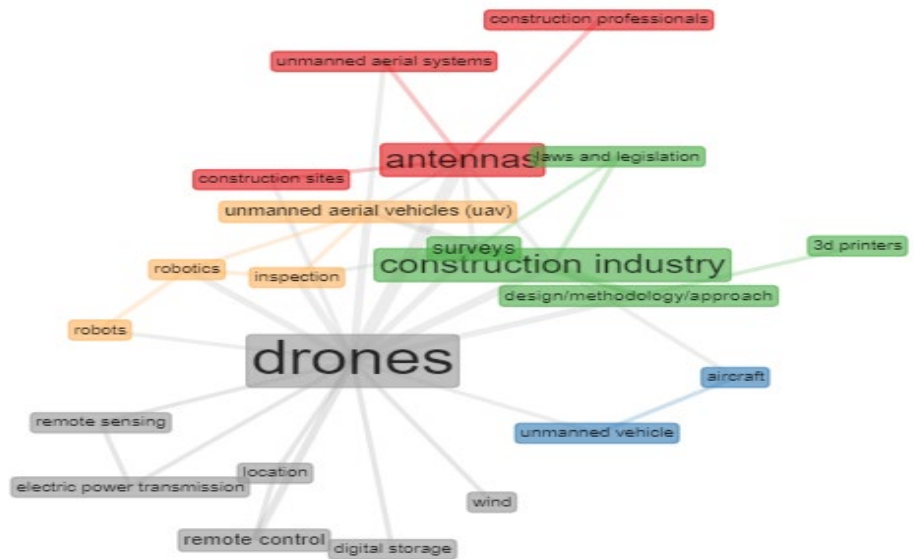


Figure 3 Thematic Collaboration Derived from the Articles Included in the Study

5. BENEFITS OF USING DRONES FOR CONSTRUCTION PROJECTS

As a remote sensing platform, drones can potentially increase the efficiency of construction project data acquisition by having much higher spatial and temporal resolutions than other remote sensing techniques [Zhou and Gheisari \(2018\)](#). In recent years, the use of drones has continued to increase, and applications have continued to develop, opening up new perspectives for environmental and wildlife management. The appearance of this technology has several advantages in acquiring high spatial and temporal resolution imagery, unlike conventional remote sensing platforms [Yoo \(2021\)](#).

The monitoring of project progress is time-consuming concerning planning and scheduling. It is tedious for site engineers to keep a real-time check on details on every corner. The use of drones will give real-time evolution of the construction site and help stakeholders manage many sites by knowing accurate dates and making good decisions in the optimal way [Matus and Mesaros \(2019\)](#).

Besides, UAVs provide high-quality images and maps for integrated and smooth communication with all partners. It also provides invaluable help and cost savings with expansive views of inaccessible and otherwise difficult and tough to navigate among locations [Dastgheibifard and Asnafi \(2018\)](#).

Large amounts of data can be captured in a short time which will lead to saving the cost [Sanson \(2019\)](#). It allows easy integration into projects, tracking site progress precisely, and handling lag time. The potential delays and issues in projects can be avoided or minimized by effectively managing time and resources [Gheisari, And Esmaeili \(2019\)](#).

The overhead view of the construction sites can be seen using drone technology. Autonomous flying machines are used by contractors to record videos that help them in planning. [Matus and Mesaros \(2019\)](#), [Dastgheibifard and Asnafi \(2018\)](#).

5.1. SAFETY OF WORKERS IN THE CONSTRUCTION SITE

Construction firms and shareholders are naturally disturbed about on-the-job injuries and examine methods to diminish risk. Drones perform surveys in unstable regions and transport contractors away from high-risk zones where casualties may occur. Drones are functioned remotely, which is useful for assessing places where sending people would be too unsafe [Yoo \(2021\)](#), [Zhou et al. \(2018\)](#), [Zhou and Gheisari \(2018\)](#).

Traditionally, the typical technique of collecting site data was done on foot or with human aerial vehicles. Construction experts have taken advantage of acquiring up-to-date photos as often as they want in real-time by using drones and avoiding dangerous workforce manipulation.

Using UAVs reduces deaths and injury risks from Construction falls, toxic chemical exposures, electrical hazards, or traumatic injury from vehicle and equipment collisions during Construction. UAVs are advantageous in warning about unsafe situations in large construction projects, from site preparation to project completion [Dastgheibifard and Asnafi \(2018\)](#). The new technology can fly over the construction site collecting real-time data from the location of personnel and equipment, hazardous materials, moving equipment, as well as the blind spots of the construction environment to prevent unsafe conditions before accidents happen.

Scope, Quality, Time, and Cost are the main constraints of a project. Drone usage in the construction sites will help the workers to enhance their performance and keep the project on their Schedule. Moreover, this will increase the quality of the existing work with less cost. Cost can be minimized from all aspects, such as lowering the insurance costs and Quality Costs. The insurance Costs can be reduced as the risks can be analyzed and mitigated in the earlier stages. The Quality Costs, such as the cost of rework, repair, or additional maintenance and inspection, can be reduced.

5.2. PROJECT RISK MANAGEMENT

The construction sector considers Risk management a crucial step in project planning and management. Moreover, the construction sector is volatile and is affected by various external factors. Usage of Drone can help the Project managers to mitigate the risks in construction Projects to an extent. A 360-degree view of the construction site and the entire building structure can be provided by Drone technology. This will help the Project risk managers to deal with any risk on the site before any safety hazards happen to the employees. Any relevant financial risks can also be avoided as drones are involved in the continuous monitoring and inspection of the Construction Sites. Legal Risks can also be mitigated to an extent by using Drone Technology. The issues related to new zones, lawsuits, and regulation changes can be efficiently dealt with. The data recorded in the drone can be used as evidence to the authorities to solve legal issues, and the progress of the project can also be tracked easily.

As many data streams are provided by drones, such as still images, Video, LiDAR, the managers involved in risk management can use the data of past projects to detect the risk factors for the future projects

5.3. PROJECT RESOURCE MANAGEMENT

According to [Keyvanfar et al. \(2022\)](#), as the demand for drones is increasing in the construction sector, software developers are involved in designing 3D Robots using drone technology. According to the PwC estimate value of labor currently being used will be replaced by drone technology by \$128 billion. Hence, the use of human resources can be replaced in the construction sector by drone technology. However, [Brusco \(2022\)](#) have suggested that drones cannot replace the job of a surveyor or an architect in construction projects. Drones can be added resources in projects along with human resources, not a replacement for human resources.

6. FINDINGS AND RECOMMENDATIONS

As a result of this research, it is now conceivable that drones are part of the robots that will revolutionize the industrialization of construction on site. Indeed, the freedom of its movements gives it a substantial advantage over other robots. Nevertheless, it is necessary to recall its limitations, which are not negligible [Branders, and Bruneau \(2017\)](#). Its three main defects are its weight limit to transport the heavy elements, its tolerance to deposit them and its very low ability to act on an element already in place. Indeed, the drone (not attached to a wall or other developed system) is a flying robot that has as support only the air, which prevents it from exerting high forces on an object [Delmonteil and Rancourt \(2018\)](#). This only allows it to lift limited loads and move them without exerting force on

other elements. The use of drones forces the building elements to become small and easily interlocking again, which goes opposite the industry.

Besides, building with drones involves reviewing the building elements in order to meet a major constraint: the vagueness of their positioning in space. The construction process also needs to be reviewed as a drone is a robot and therefore needs to be automated. Between 2017 and 2019, researchers focused on 3 main aspects: - The development of suitable building elements for transport and placement by a drone, as well as their gripping system - The development of the drone itself, its positioning system, and its technical aspects - The design of an application to assemble a basic structure with simple elements and the development of control algorithms for the construction process [Custers \(2017\)](#).

The use of drones in construction sites would radically change the progress of construction projects: it would bring to the site all their precision and speed of execution, well exploited in factories [Branders and Bruneau \(2017\)](#). Combined with the intensive operation (24/7), these strengths would shorten construction times and increase their quality. However, the automation of construction sites is confronted with two major problems: the mobility of robots and the uniqueness of the product to be produced [Gallet \(2019\)](#). The drone is a possible solution to this first problem but seems limited by other parameters such as the load it can carry, its displacement tolerance and its ability to act on fixed elements [Delmonteil and Rancourt \(2018\)](#). Despite the speed of development of current technologies, it is unlikely in the "near" future that robots will be able to build structures without the help of workers.

The current research is a Systematic Literature Review on the Deployment of Drone Technology in Construction Projects. Future researchers can utilize quantitative or mixed method approaches in the domain of study. Most of the articles in the study domain analyse the benefits of using drone technology or evaluate the technical aspects of using the same. Future researchers can analyse the following areas in the domain:

- Human resource replacement of drones in projects can be a potential future research area.
- Risk Management of projects can be further studied in Construction projects.
- Occupational Safety and Health of Construction workers with the aid of drone technology can be further analysed.
- Feasibility studies of using drone technology can be conducted in various other sectors.

7. CONCLUSION

It should be noted that the construction environment is far from being optimized: waste of materials, high labor costs, numerous inaccuracies and errors on site or the difficulty of shortening deadlines directly (and too much) dependent on human resources. That is when the idea of construction automation makes its way, as can be compared with the massive use of robots in the automotive industry. Using remotely controlled or programmed robots to perform a task autonomously can thus have many advantages and huge savings in Construction Projects. Thus, drones are a valuable technical advantage. Their usage in the construction sector will only grow in the future since they can quickly capture high-quality data and substantially reduce the danger to a project team's safety.

CONFLICT OF INTERESTS

None.

ACKNOWLEDGMENTS

None.

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