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Innovative Drone Technology for Property Maintenance

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Abstract

The use of drone technology in property maintenance provides new and creative solutions for managing high-rise buildings and hard-to-reach areas. This study looks at how drones can be used in this field, focusing on how effective they are and the challenges of using them. The research was based on interviews and reviewing articles. Through qualitative research involving interviews with industry experts like Dr. Rajaratnam, Najihah Ibrahim, and Wan Hasyidan, the findings reveal that drones significantly enhance inspection efficiency, improve safety, and reduce costs through capabilities such as AI-powered predictive maintenance and real-time data collection. Dr. Rajaratnam emphasized drones' cost-effectiveness and safety, while Najihah Ibrahim and Wan Hasyidan highlighted privacy concerns and regulatory barriers as key challenges. The study identified five main contributions such as improving operational efficiency, enhancing safety, reducing costs, addressing regulatory restrictions, and advancing technological integration. However, there are challenges, such as rules, technical issues, and costs. This study helps with ideas for managing properties in a more sustainable way and gives tips for solving problems with drone use. Future studies should focus on better technology and rules to make drones even more useful.

1. Introduction

The adoption of drone technology for property maintenance represents a significant evolution in the building industry towards increased productivity and creativity. Drones offer innovative opportunities to enhance resource optimization, maintenance planning, and property inspection procedures in the real estate sector due to their advanced imaging capabilities and flexible viewpoints. Property maintenance aims to ensure the appearance, safety, and functionality of buildings and structures through various activities, with high-rise buildings and inaccessible locations posing unique challenges that require creative solutions to ensure durability and proper upkeep. Traditional property maintenance methods, while effective in many cases, may not always meet the specific needs of high-rise buildings and are difficult to reach locations, leading to potential maintenance issues.

The integration of drone technology into property maintenance activities is a promising innovation that can address these challenges. Drones equipped with advanced imaging features and sensor capabilities present an opportunity to transform high-rise building inspection procedures, enable data-driven decision making for maintenance projects in hard-to-reach areas, and provide a comprehensive view of structural issues. By incorporating drone technology into workflows, property managers can improve operations, reduce risks, and allocate resources more efficiently, ultimately enhancing the sustainability and efficacy of property management practices in the digital age.

1.1 Research Background

The transformative potential of drone technology in the construction industry, as discussed in the article "Application of Drone technology in construction industry: A study 2012-2021," provides an idea for the research background for my final year project, "Innovative Drone Technology for Property Maintenance." Property managers may improve maintenance operations by using drones that are equipped with advanced imaging features and perspective flexibility. This can be achieved through effective inspections, proactive repair plans, and optimal resource allocation. Drones provide a special perspective on structural problems, risks, and maintenance needs (Mahajan, 2021). This helps to optimize workflows, enhance safety procedures, and improve decision-making processes. Drone integration in property maintenance promotes sustainable and technologically advanced real estate practices while also increasing operational effectiveness and cost savings. To promote effective and long-lasting property management techniques in the digital era, this research project is to investigate the viability, advantages, and difficulties of using drone solutions in property maintenance.

The investigation of "Innovative Drone Technology for Property Maintenance" aims to strategically integrate drone technology, in line with the study's emphasis on the technology's revolutionary potential, and it draws on the insights of (Mahajan, 2021). By increasing operational effectiveness, safety procedures, and financial savings in property maintenance operations, this integration is anticipated to contribute to sustainable and successful real estate practices in the digital age. (Emimi et al., n.d.) stated the advantages of employing drones with modern imaging features for property maintenance, underlining the technology's disruptive potential in the construction sector. Property managers may strengthen security procedures, streamline workflows, and make more knowledgeable decisions by utilizing drones with modern imaging characteristics and sensor capabilities.

1.2 Problem Statements

Start with property maintenance and focusing on the difficulties in maintaining high-rise structures and hard-to-inspect areas, the workflow must be established. Analysing an illustration of failures brought on by unsatisfactory maintenance procedures, the study seeks to understand how technology may be applied to address maintenance difficulties. Drone integration into property maintenance activities is one new technology innovation option being considered.

The difficulties with property maintenance are the key research issues this study attempts to solve, especially when it comes to high-rise buildings and hard-to-inspect areas. The report of poor maintenance methods' implementation highlights the urgent need for creative solutions to increase maintenance effectiveness, lower risks, and strengthen property management decision-making procedures. There is an urgent need for new technology to efficiently solve the maintenance issues posed by high-rise buildings andinaccessible locations, as standard techniques to maintenance are lacking.

1.3 Research Question

a) How can drone technology be effectively integrated into property maintenance?

b) What are the challenges in adopting drone technology for property maintenance?

1.4 Research Objectives

a) To evaluate the effectiveness of drone technology in property maintenance.

b) To identify challenges associated with the adoption of drone technology in property maintenance

1.5 Aim and Scope of the Study

The research aims to evaluate the feasibility and effectiveness of integrating drone technology into property maintenance practices for enhancing inspection, maintenance planning, and resource allocation.

1.6 Significance of Study

The investigations of new technical approaches, particularly the use of drones, to overcome obstacles in property maintenance operations particularly in high-rise buildings and inaccessible areas is what makes this study significant. The research seeks to contribute to improving efficiency and effectiveness in property maintenance procedures by examining the weaknesses in traditional maintenance techniques and suggesting drone technology as a possible alternative. The construction industry's maintenance procedures might be completely changed by this research, improving building efficiency, safety, and cost-effectiveness.

2. Literature Review

A This chapter is about exploring innovative solutions for property maintenance in high-rise buildings and inaccessible locations, with a specific focus on the transformative potential of drone technology in addressing maintenance challenges.

2.1 Introduction

Property maintenance is essential to ensure the durability, security, and operation of buildings and structures. Maintaining high-rise structures and inaccessible locations can be challenging and requires creative strategies. This study examines the drawbacks of conventional maintenance techniques, challenges in maintaining towering structures, risks of poor maintenance, and how technology, especially drones, can transform property maintenance procedures.

2.2 Building Maintenance Management

Research by Lateef (2009) on maintenance management in PERKESO buildings in Malaysia highlights the importance of performance measurement in construction sustainability. Emphasis is placed on data-driven decision-making and continual improvement in building maintenance to increase the value and durability of constructed assets.

2.3 Benefits of Building Maintenance

Chan (2014) emphasizes that building maintenance plays a crucial role not only in preserving a building's original functional and aesthetic condition but also in enhancing its overall value and extending its lifespan. Regular and effective maintenance helps prevent structural deterioration and ensures that facilities remain safe, efficient, and appealing for occupants. Furthermore, sustainable renovation practices—such as the use of energy-efficient systems, environmentally friendly materials, and waste reduction strategies—are essential in minimizing pollution and contributing to a healthier environment. These practices also improve the comfort, productivity, and well-being of tenants, aligning with broader sustainability goals. Chan further argues that maintenance should not be treated as a reactive measure but rather as a proactive and strategic component of organizational planning and decision-making. By integrating maintenance into long-term management strategies, organizations can achieve cost savings, enhance asset performance, and generate lasting value for all stakeholders..

2.4 Property Maintenance Challenges

2.4.1 Traditional Maintenance Methods and Their Limitations: Traditional high-rise building maintenance approaches, such as scheduled repairs and manual recording systems, can result in higher costs and inefficiencies. Preventive maintenance is essential but often limited using outdated methods.

2.4.2 Complexities of High-rise Buildings and Inaccessible Locations: High-rise buildings have complex systems that require regular maintenance, which is often hampered by difficult-to-reach areas and the need for specialized equipment and safety measures. Effective maintenance requires addressing these challenges with proactive and specialized approaches.

2.4.3 Safety Hazards and Inefficiencies in Property Upkeep: Safety hazards in maintenance tasks, especially in high-rise buildings, include working at heights and in confined spaces, which can lead to accidents. Operational inefficiencies such as poor record-keeping and insufficient financial resources can further complicate maintenance efforts

2.5 Failures in Maintenance Procedures

2.5.1 The Effect of Inadequate Maintenance on Building Integrity: Delayed repairs can compromise structural integrity and safety, leading to significant repair costs and legal liabilities. Proactive maintenance is crucial to avoid safety hazards and structural defects.

2.5.2 Consequences of Delayed or Insufficient Repairs in Building Maintenance: Delayed maintenance can lead to increased repair costs, structural damage, safety risks, and unexpected liabilities such as legal action and compliance issues. Proactive maintenance helps prevent these issues by addressing problems early.

2.5.3 Proactive Maintenance Practices: Implementing a comprehensive maintenance plan that includes regular inspections, and timely repairs can significantly reduce long-term costs and risks. Effective maintenance planning relies on good planning, budgeting, and advanced management systems.

2.6 Technology Solutions for Maintenance Problems

2.6.1 Introduction to New Technological Advancements in Property Maintenance: New technologies, particularly drones, offer innovative solutions for property maintenance, especially in high-rise and difficult-to-access areas. Drones provide advanced imaging and inspection capabilities, enhancing maintenance efficiency and safety while reducing costs.

2.6.2 Role of Drones in Overcoming Maintenance Challenges: Drones can address limitations in traditional maintenance by providing access to hard-to reach areas and enabling detailed inspections. They reduce the need for manual inspections and scaffolding, thus lowering risks and costs.

2.6.3 Benefits of Integrating Drone Technology into Maintenance Workflows: Integrating drones into maintenance workflows improves productivity, precision, and safety. Drones enable thorough inspections and data collection, aiding in proactive maintenance and cost savings over time.

2.7 The Current Drone Applications in Property Maintenance

Global case studies illustrate the successful use of drones in property maintenance, such as in Singapore for building façade inspections and in the United States for roof condition assessments during severe weather events. In Malaysia, drones are increasingly used for building inspections, enhancing the safety and efficiency of maintenance tasks. Examples include the use of drones for monitoring the structural integrity of the Petronas Towers in Kuala Lumpur.

3. Research Methodology

3.1 Research Flowchart

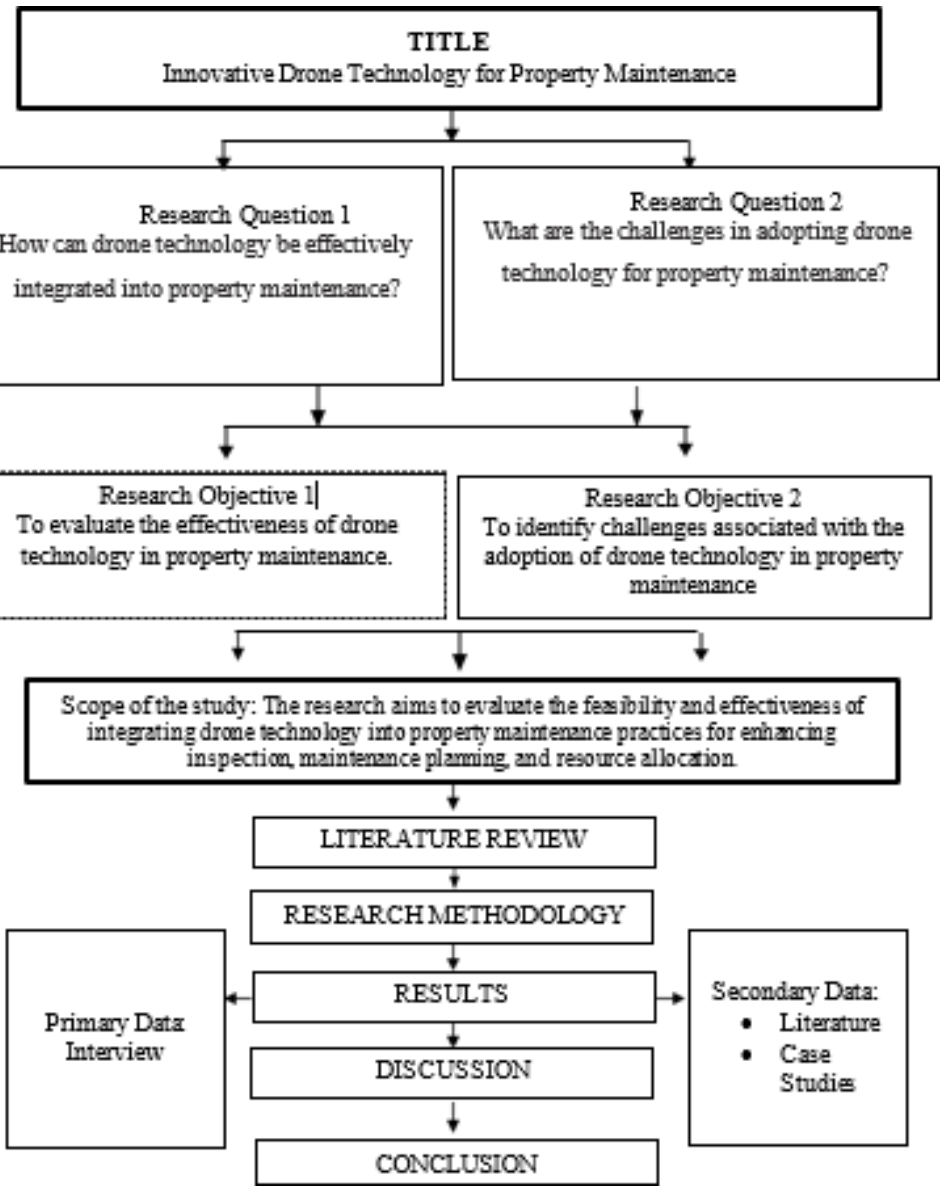

Figure 1 Research Flowchart

3.2 Research Design

The research method was used to investigate the adoption of drone technology in property maintenance. The study uses qualitative research technique, including interviews with property managers, to obtain detailed information on the practical matters, advantages, and challenges related with using drone technology in property management activities

3.3 Data Collection

3.3.1 Primary Data Collection:

a) Interview Design: Semi-structured interviews use a combination of open-ended and targeted questions to lead the conversation while enabling respondents to freely share their experiences and insights. Questions address the obstacles, advantages, regulatory problems, and technological hurdles of using drones in property management.
b) Participant Selection: Property managers from a variety of properties, including residential, commercial, and industrial buildings, are chosen to present a wide range of viewpoints. Participants are chosen based on their experience and participation in property upkeep.
c) Data Collection Process: Interviews are conducted in person, by phone, or by video conferencing, depending on the participants' convenience and availability. Each interview is recorded and transcribed for in-depth examination.

3.3.2 Secondary Data Collection:

a) Literature review: A thorough assessment of academic publications, industry reports, and case studies involving drone technology in property management is done. This allows for context for the main data while also providing a theoretical foundation for the investigation.
b) Industry Reports and Case Studies: Analysing industry reports and successful case studies in which drone technology has been used for property maintenance. These sources offer practical examples and illustrate potential problems and rewards that might help guide primary research.

3.4 Data Analysis

The data analysis stage includes organizing and evaluating the qualitative data gathered during the interviews. This involves summarizing the interviews and discovering common themes, patterns, and insights. The analysis's purpose is to synthesize qualitative data to gain a full understanding of the feasibility and effectiveness of drone technology in property maintenance. The findings of this investigation are utilized to develop practical recommendations and methods for successfully implementing and integrating drones into the real estate sector.

4 Results and Discussion

This section analyses the findings derived from interviews with industry experts, emphasizing the integration of drone technology in property maintenance. The discussion aligns the results with the research objectives, focusing on the effectiveness, challenges, and potential of drone technology.

4.1 Respondent Demographic

Table 1 *Respondent Demographic*

Attribute	Respondent 1	Respondent 2	Respondent 3
Name	Dr. Rajaratnam	Najihah Ibrahim	Wan Hasyidan Bin Wan Hussein
Organization	AI Property Management Company	SA Property Management Sdn Bhd	Drone Tech Hub, ILP Mersing
Position	Senior Expert	Building Manager	Drone Technical Advisor
Area of Expertise	Drone and AI Integration	Operational Management	Drone Regulations and Competency Training
Years of Experience	Over 15 years	10 years	Over 12 years

4.2 Data Collection

The findings from this study are organized into thematic categories that align with the objectives of the research. Table 1 summarizes the themes, sub-themes, and their descriptions.

Table 2 *Summary of Key Findings*

Theme	Sub-theme	Description
Effectiveness	Offering New Experiences	Drones provide innovative solutions, offering aerial perspectives and real-time monitoring.
	Accessibility	Enable safe and efficient access to hard-to-reach areas.
	Cost Efficiency	Reduce manual labor and equipment costs, yielding long-term savings.
	User-Friendliness	Easy to operate with intuitive interfaces and structured training programs.
	Effective Platform	Serve as centralized tools for data collection, analysis, and visualization.
Challenges	Regulatory Barriers	Strict guidelines and operational restrictions in urban areas.
	Privacy Concerns	Data security issues and stakeholder apprehensions about surveillance.
	Technical Limitations	Limited battery life, signal interference, and weather constraints.

Workforce Adaptation	Need for reskilling workers and addressing concerns about job displacement.
Cost and Investment	High initial costs for drones and associated training programs.
Public Perception and Acceptance	Resistance from stakeholders due to misconceptions or lack of awareness.

4.3 Discussion of Findings

4.3.1 Effectiveness of Drone Technology

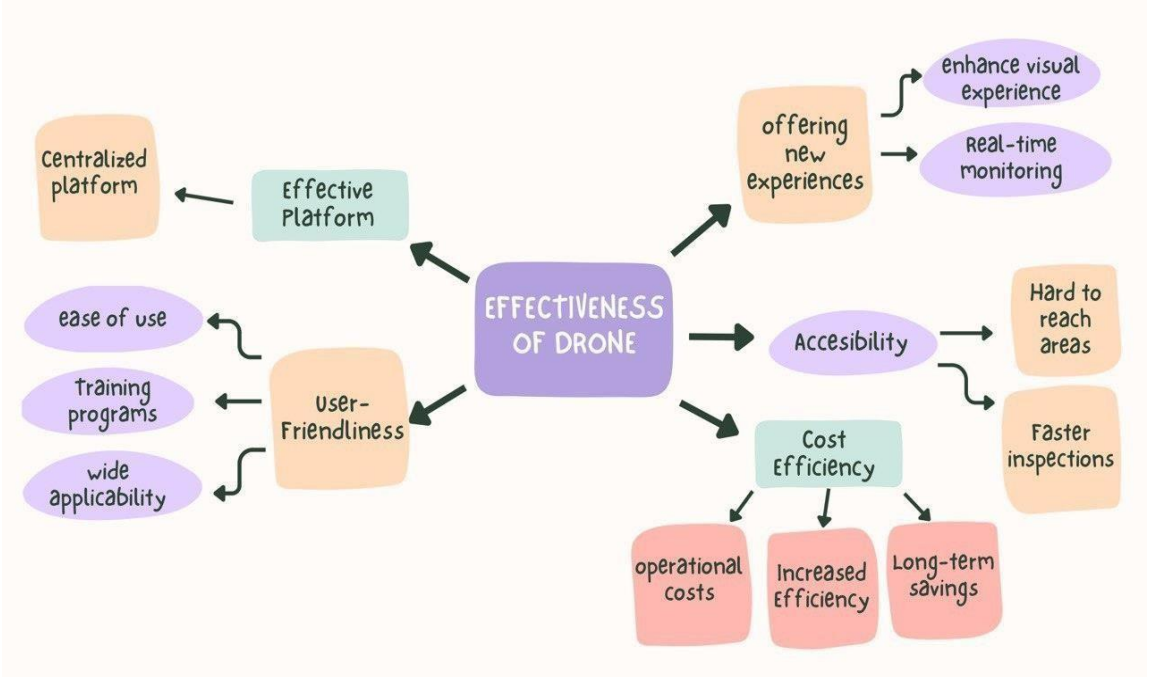

Figure 2 *Effectiveness of Drone*

4.3.2 Offering New Experiences

Drones provide innovative solutions by enabling aerial inspections and real-time data collection. Dr. Rajaratnam emphasized, *"Drones offer new ways to inspect inaccessible areas, providing unparalleled insights for property maintenance."* This capability transforms traditional approaches, allowing for more efficient and precise workflows.

Wan Hasyidan supported this view, stating, "*Drone technology provides new angles and perspectives. These tools give us the ability to review and inspect areas we could never physically access safely before*." This new dimension of property inspection ensures that all areas, regardless of their complexity or inaccessibility, are evaluated thoroughly. The aerial imagery captured by drones provides high-quality data that contributes to more informed decision-making processes

4.3.3 Accessibility

Accessibility is one of the most important advantages of drone technology in property maintenance. Dr. Rajaratnam highlighted, "*With drones, you don't have to send people to climb buildings or go into unsafe spaces. It's safer and much more practical*." This advantage becomes particularly evident in high-rise buildings or infrastructure located in hazardous environments, where physical inspections would be both time-consuming and dangerous.

Drones address challenges related to inspecting high-rise buildings and confined spaces. They eliminate the need for manual access to dangerous areas. Najihah Ibrahim stated, *"With drones, inspections are safer and faster, reducing risks for personnel and enhancing coverage."* This capability reduces the physical and operational limitations associated with traditional inspection methods, such as scaffolding or heavy equipment. Drones also eliminate the need for extensive planning and manpower, enabling inspections to be conducted swiftly and with minimal disruption to ongoing operations.

4.3.4 Cost Efficiency

Although drones require an initial investment, they result in significant long-term savings. By reducing labour and equipment costs, drones make inspections faster and more cost-effective. Najihah explained, *"The time and cost savings from using drones make them a smart choice for property managers."*

The financial and productivity benefits of drones are evident in property maintenance applications. Dr. Rajaratnam pointed out, *"Drone technology is very cost-effective and safe, reducing manual labour and associated risks."* By eliminating the need for extensive manpower, drones significantly lower operational costs. These savings extend to equipment rentals, insurance costs for high-risk tasks, and time spent on prolonged inspections.

4.3.5 User-Friendliness

The user-friendly nature of drones has contributed to their widespread adoption in property maintenance. Najihah Ibrahim noted, *"Most drones are equipped with easy-to-use controls and user-friendly interfaces, making them accessible even for those without technical experience."* This accessibility ensures that a wide range of users, including property managers and technicians, can operate drones with minimal training.

Drones are designed with intuitive controls, making them accessible even to non-technical operators. Training programs, such as the Sijil Kompetensi Operasi Drone (SKOD), simplify adoption and ensure safety. Wan Hasyidan noted, *"Structured training ensures proficiency and compliance with safety standards."* He also stated, *"These training programs ensure operators, regardless of their technical background, are proficient and compliant with safety standards."*

4.3.6 Effective Platform

Drones act as centralized tools for data collection, visualization, and predictive maintenance. Dr. Rajaratnam highlighted, *"Drones provide accurate data that enable property managers to make informed decisions quickly, improving maintenance efficiency."*

Wan Hasyidan emphasized the role of drones in predictive maintenance, stating, *"AI-powered drones can analyse trends and predict potential failures before they occur, which is a game- changer for asset management."* This proactive approach ensures that maintenance teams are always a step ahead, addressing issues before they escalate into major problems. As highlighted in the thematic analysis, drones serve as a comprehensive maintenance platform that enhances both the quality and reliability of outcomes.

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4.3.7 Challenges in Adoption

a) Regulatory Barriers

Strict aviation regulations limit drone operations in urban areas. Compliance with guidelines, such as CAD 6011, is essential for safe use. Wan Hasyidan explained, *"Regulations are necessary but can complicate adoption for property managers."*

The complexities of these regulations can create challenges for property managers who are eager to implement drone technology. As Wan Hasyidan highlighted*, "You cannot use drones freely in urban areas due to restrictions and privacy issues"*. Permits and certifications like the Remote Pilot Certificate of Competency are essential.

b) Privacy Concerns

As drones collect and transmit large amounts of data, especially visual and geographical data privacy and data security become significant concerns. Privacy issues are particularly pronounced in residential areas, where the perception of surveillance can cause discomfort among residents. Najihah Ibrahim expressed this sentiment, saying, *"Drones in residential areas might accidentally invade personal spaces, causing discomfort among residents."* This highlights the unease some property owners may feel about their homes being filmed or monitored, even if the intent is solely for maintenance purposes.

To address these concerns, property managers must take steps to implement strict data protection measures. This includes using encrypted data transmissions, storing data securely, and ensuring that all drone operations adhere to privacy regulations like the General Data Protection Regulation (GDPR) or local privacy laws. Transparency is also essential. Wan Hasyidan emphasized the importance of open communication with stakeholders, noting, *"Clear guidelines on drone usage and data collection can help build trust among property owners and residents."* This could involve informing residents about when drones will be operating and explaining how their data will be used, ensuring that all parties are comfortable with the technology.

c) Technical Limitations

Issues such as limited battery life, signal interference, and weather constraints impact drone performance. Dr. Rajaratnam suggested, *"Advancements in AI and modular designs can optimize drone operations and mitigate technical challenges."* Drones are often deployed in challenging environments like tall buildings or remote areas where their functionality could be compromised by these limitations.

d) Workforce Adaptation

Additionally, there are concerns about workforce adaptation. Dr. Rajaratnam highlighted the potential for job displacement due to the automation capabilities of drones, saying, *"Because drones automate many tasks, there is a fear that jobs might be lost."* This is a legitimate concern in industries where manual labor is replaced by automation.

The shift to drone technology requires reskilling and training for maintenance personnel. Resistance may arise from fears of job displacement. Dr. Rajaratnam noted, *"Training programs ensure workers adapt to new roles, maintaining relevance in a tech-driven industry."*

e) Cost and Investment

High initial costs for drones, training, and maintenance pose financial barriers. Najihah suggested phased adoption, stating, *"Starting small and scaling gradually can help property managers manage costs effectively."*

4.3.8 Real-World Applications

(a) High-Rise Building Maintenance

Inspecting high-rise buildings requires the use of scaffolding or cranes, both of which areexpensive and pose safety risks to workers. The introduction of drones in this space has revolutionized the way building facades are inspected. Drones equipped with high-resolution cameras can quickly and safely capture images and videos of building exteriors, allowing property managers to identify issues such as cracks, water damage, and wear.

The time saved by using drones is one of the most significant benefits. Traditional methods of building inspection can take days to complete, with numerous workers involved. In contrast, drones can accomplish the same task in a matter of hours, cutting down on both labor costs and the time it takes to identify potential maintenance issues. The safety benefits are also clear: drones eliminate the need for workers to operate in dangerous environments at great heights, reducing the risk of accidents.

(b) Utility Inspections

Another important application of drone technology in property maintenance is for inspecting utility systems like water tanks and solar panels. These types of inspections are traditionally difficult to carry out due to the need for specialized equipment or because the systems are in hard-to-reach areas. With drones, these tasks become much more manageable. Drones can fly over large areas to assess the condition of water tanks, solar panel arrays, and other utility installations, capturing both visual and thermal images.
For example, a solar panel inspection that would typically require workers to manually inspect each panel on a rooftop can now be done much more quickly with drones. Not only is this process faster, but it also provides more accurate data. Drones can use infrared sensors to detect issues like overheating panels or damaged wiring that might otherwise go unnoticed during a manual inspection. This allows property managers to address problems early before they become costly to repair.

4.3.9 Comparative Analysis: Drones vs. Traditional Methods

(a) Efficiency

Drones' complete inspections in hours, compared to days using traditional methods. The speed of inspections is another area where drones outperform traditional methods. For example, drones can complete property inspections in a fraction of the time it would take using manual methods. Where scaffolding or cranes may take hours or even days to set up, drones can be deployed almost immediately and inspect hard-to-reach areas like rooftops, facades, and solar panels in just a few hours. The ability to quickly gather data means that property managers can act swiftly on maintenance issues, preventing potential problems from escalating.

(b) Safety

Safety is a critical consideration in property maintenance, particularly when it involves working at heights or in hazardous environments. Traditional methods often expose workers to significant risks, such as falls from scaffolding or accidents while operating cranes. These risks not only put workers' lives in danger but also increase insurance costs and the likelihood of work stoppages due to accidents. By removing the need for scaffolding or manual labor in hazardous areas, drones reduce workplace risks significantly.

(c) Cost Savings

Although initial costs are high, drones reduce long-term expenses through decreased reliance on labour and equipment. Traditional property maintenance methods often require significant financial investment. For example, inspecting high-rise buildings typically involves hiring a team of workers, setting up scaffolding, or using cranes and other heavy machinery. These methods not only increase the overall cost but also involve recurring expenses for equipment maintenance, worker safety gear, and insurance coverage.

(d) Sustainability

Drones consume less energy and produce fewer emissions compared to traditional methods, supporting environmental sustainability.

4.3.10 Future Potential

a) AI and Predictive Maintenance

AI-powered drones enable real-time data analysis and predictive maintenance. Dr. Rajaratnam stated, *"AI enhances drone efficiency, identifying issues before they escalate."*

b) Autonomous Drones

Future drones are expected to operate autonomously, conducting inspections and minor maintenance tasks without human intervention. This innovation promises to revolutionize property management workflows.

c) 5G Connectivity

The introduction of 5G technology enables faster data transfer, allowing property managers to monitor inspections in real-time. Wan Hasyidan emphasized, *"5G will enhance communication between drones and managers, improving operational efficiency."*

5. Summary

This research explored the integration of drone technology into property maintenance, with a particular emphasis on its application in high-rise buildings and areas that are difficult or dangerous to access. The study revealed that drones have the potential to revolutionize traditional maintenance practices by enabling more accurate and efficient inspections, reducing the need for manual labor in hazardous environments, and significantly improving safety for maintenance personnel. Moreover, the use of drones can lead to substantial cost savings and increased operational efficiency through faster data collection, real-time monitoring, and detailed visual assessments of building conditions.

However, the research also identified several key challenges that must be addressed before widespread adoption can occur. These include stringent regulatory restrictions governing drone operations, technical limitations such as battery life and data processing capacity, as well as ethical and legal concerns surrounding privacy and surveillance. Additionally, the initial financial investment required for drone procurement, training, and data management infrastructure remains a barrier for many organizations.

Drawing upon qualitative interviews with industry professionals and a comprehensive review of existing literature, the study concluded that drones represent a promising, sustainable, and innovative solution for modern property maintenance. Their ability to facilitate predictive maintenance, support data-driven decision-making, and improve asset management efficiency underscores their potential to transform the future of building maintenance and facility management practices.

5.1 Accomplishments of Objectives

The research successfully achieved its objectives by demonstrating the effectiveness of drone technology and addressing the challenges associated with its adoption. Drones have been shown to improve accuracy, enhance safety, and streamline property maintenance processes. The integration of artificial intelligence further amplifies their potential, allowing for predictive maintenance that reduces long-term costs and operational risks. For example, one respondent emphasized how drones reduce reliance on manual labor and minimize risks associated with high- rise inspections. At the same time, the study highlighted challenges, including regulatory restrictions, privacy issues, and technical limitations such as limited battery life and signal interference. These barriers, however, can be addressed through phased adoption, structured training programs, and compliance with regulatory frameworks.

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5.2 Recommendations

Based on the findings, several recommendations are proposed to facilitate the successful adoption of drone technology in property maintenance. For property managers, a phased implementation approach is suggested, starting with smaller-scale tasks such as roof inspections to evaluate the technology's effectiveness. Investment in training programs and certifications, such as the Sijil Kompetensi Operasi Drone (SKOD), is critical to ensuring safe and effective operations. Additionally, collaboration with regulatory bodies is essential to streamline the permitting process and ensure compliance with legal requirements.

Policymakers should consider developing clear and flexible regulations to balance safety with innovation. Offering financial incentives, such as subsidies or tax benefits, can encourage broader adoption, especially among smaller property management firms. Future research should explore the long-term economic impact of drones and examine their application in diverse geographic and regulatory contexts to provide a global perspective on their adaptability and benefits.

5.3 Limitations of the Study

This study was limited by the availability of respondents experienced in drone technology within the property maintenance industry, reflecting the nascent stage of adoption in Malaysia. The research primarily focused on urban areas, which may not fully capture the challenges and opportunities in rural settings. Expanding the scope of future studies to include international contexts or rural areas would provide a broader understanding of technology's potential applications.

6. Conclusion

In conclusion, the integration of drone technology represents a paradigm shift in property maintenance, addressing long-standing challenges associated with high-rise structures and inaccessible areas. Drones have proven to be effective tools for enhancing efficiency, safety, and cost-effectiveness in maintenance operations. However, the successful adoption of this technology requires careful planning, investment in workforce training, and adherence to legal frameworks. While challenges such as regulatory and privacy concerns persist, they can be mitigated through collaboration among stakeholders and strategic approaches. As advancements in artificial intelligence, battery life, and connectivity continue to evolve, drones are poised to become indispensable in transforming property maintenance into a safer, more sustainable, and efficient practice.

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Conflict of Interest

There is no conflict of interests regarding the publication of the paper

Authors' contribution

The authors confirm their contribution to the paper as follows: ***study conception and design***: Aliff Khuzairi Mazelan, Sr. Zarina Shamsudin ; ***data collection***: Aliff Khuzairi Mazelan, Sr. Zarina Shamsudin; ***analysis and interpretation of results***: Sr. Zarina Shamsudin ;***draft manuscript preparation***: Aliff Khuzairi Mazelan, Sr. Zarina Shamsudin, Indera Syahrul Mat Radzuan, Masfaliza Mohsen. All authors reviewed the results and approved the final version of the manuscript.

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