Drones and Technopreneurship in Malaysia: Unlocking the Economic Potential of Drones in Built Environment Development

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ABSTRACT

Drones, with diverse technological capabilities, are poised to revolutionise various traditional tasks, particularly in-built environment development while driving economic growth, innovation, and job creation. Within the Malaysian context, drones have evolved beyond recreational use to become sophisticated unmanned aerial vehicles with untapped business potential. Against this backdrop, this paper explores a comprehensive review of drone development in Malaysia. Using a multidisciplinary approach, the review includes selected publication data from academic journals and online media published between 2018 and 2023, complemented with insights gathered from expert interviews. Aiming to bridge the discursive gap surrounding emerging drone technologies, the review focuses on identifying patterns and trends in recent Malaysian publications on drone applications, as well as understanding current issues related to its technology adoption. The thematic findings reveal a notable surge in interest in drone-related publications and draw clear connections between drone applications and diverse industrial sectors over the past six years. The paper emphasises critical issues such as community acceptance, the transforming landscape of business, diverse industry applications of drone technology, and government strategies for advancing drone technology. As a preliminary study, this paper establishes the foundation for leveraging the benefits of drone technology within the broader context of the built environment, social, and economic landscape. By shedding light on the evolving drone ecosystem in Malaysia, the paper contributes to fostering informed discussions and strategic initiatives in the integration and advancement of drone technologies. Thus, it offers valuable insights for professionals, economists, engineers, policymakers, and researchers alike.

Keywords: Built Environment Development, Drones, Economic Growth, Technology Adoption, Technology Trends

1. INTRODUCTION

In the evolving global landscape, the successes achieved in military drone applications set the stage for a dynamic future in the business realm. Despite being in the early stages of technological adoption, enterprise drones hold immense promise, primarily due to their anticipated cost-effectiveness. This affordability is poised to attract businesses, creating extensive opportunities for the integration of drone technology across various industrial sectors (Jackman & Jablonowski, 2021).

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The global surge in drone technology adoption is not only transforming industries worldwide but also holds particular significance for Malaysia. In fields such as construction, logistics, agriculture, and environmental monitoring, drones have the potential to revolutionise task performance in ways that align with Malaysia's Fourth Industrial Revolution (IR4.0) agenda. As businesses increasingly recognise the potential benefits of drone technology, a vibrant market is expected to emerge. This growth is likely to stimulate innovation, leading to the development of more advanced and specialised drones tailored to meet the unique needs of various industries. Furthermore, the drone industry is likely to create new job opportunities and fuel economic growth.

A significant expansion in the drone market is anticipated, driven by lucrative prospects in both consumer and commercial domains. This profitability creates an environment conducive to stakeholders recognising the profound impact of drone technology. Drones have already showcased their operational prowess by supplanting conventional methods, reducing carbon footprints, and contributing to environmental well-being. The trajectory of drone technology indicates a global phenomenon in the coming years, as industries increasingly strive to harness its potential for social inclusion, economic development, and environmental sustainability (Eiris et al., 2021; Elghaish et al., 2021; Sakib et al., 2022; Bayomi & Fernandez, 2023; Bogue, 2023). The competitive pricing of drone software and hardware, combined with advancements in artificial intelligence and analytics, has captured the interest of various sectors, leading to increased investments in drone economics both globally and locally.

2. BACKGROUND

In the local context of Malaysia, drones, as a type of technological Unmanned Aerial Vehicles (UAVs), have evolved from recreational hobbies to sophisticated autonomous robotics platforms, offering an abundance of untapped business applications. For instance, drones are now primarily deployed in two prominent industries: agriculture and construction. In agriculture, they serve as a supplementary tool for precision farming, while in construction, they are revolutionising site surveys and enhancing safety inspections. Their proven benefits in replacing conventional operations, improving operational management, and promoting environmental sustainability have established drones as pivotal contributors to the country's industrial development. Recognising this potential, the Malaysian government is eager to bolster the drone technology sector, envisioning its global market expansion as a strategic initiative to invigorate the local economy (MDEC, 2022: 24-28; Abd Manan & Abd Halin, 2023; Khaw, 2024).

In the realm of entrepreneurship in technology, resistance to adopting drone technology, as noted by Chamata (2016), is a common challenge innovators face when introducing disruptive technologies. Entrepreneurs working with UAVs must consider societal, regulatory, and market acceptance when introducing such technology into the local market. Despite Malaysia's overall embrace of technological advancements across various industries, the slower adoption of drones underscores the importance of understanding market readiness and consumer behaviour. For tech entrepreneurs, gaining insight into the patterns and trends of UAV implementation is crucial not only for developing innovative products but also for strategically positioning themselves in the market. This knowledge can guide product development, marketing strategies, and regulatory navigation, aligning with the specific needs and concerns of both industries and the public.

From this perspective, this paper seeks to address existing gaps in the literature by conducting a comprehensive review of drone applications within the Malaysian context. Initially, we investigated academic journal articles and popular media sources to extract the latest insights on drone implementation. Acknowledging the shortcomings of past thematic discussions on drone practices in the country, our research strives to provide a thorough overview. To accomplish this, we not only draw from existing literature but also conduct preliminary expert interviews to collect first-hand perspectives on the ongoing development of drone technologies in Malaysia.

The objective of this paper thus revolves around addressing the following two key questions to facilitate a thematic review:

- What patterns and trends characterise the application of drones in recent publications in Malaysia?
- How do insights gathered from expert interviews reveal the current issues related to the adoption of drone technology in Malaysia?

3. METHODOLOGY

In response to the questions raised above, we have developed a methodological framework for data acquisition, as depicted in Figure 1. This framework adopts a multidisciplinary approach to gather data from expert interviews, academic journals, and articles in popular media.
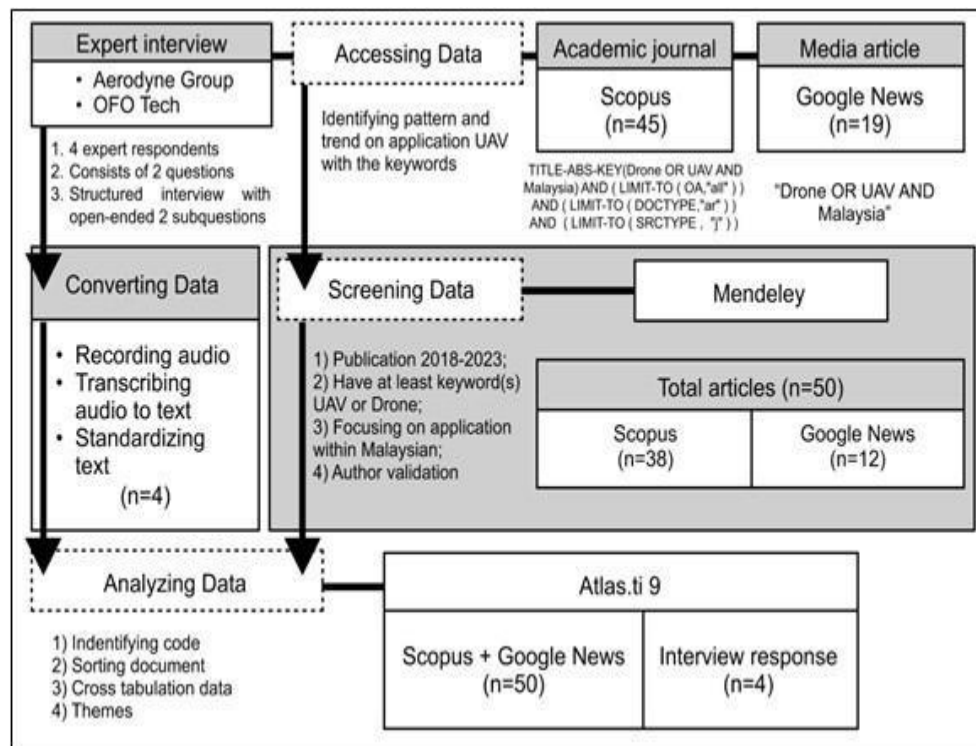

Figure 1. Methodological Framework on Data Acquisition

3.1 Accessing Publication Data

The collection of primary publication data involves two phases, encompassing academic papers and popular online media articles. For the first phase, we conducted an exploratory search in academic databases to retrieve updated and reliable academic papers by following these procedures:

- We used specific keywords (TITLE-ABS-KEY "Drone OR UAV AND Malaysia") and applied filters (LIMIT-TO (OA, "all"), LIMIT-TO (DOCTYPE, "ar"), LIMIT-TO (SRCTYPE, "j") on large online citation libraries available on the Scopus platform.
- To focus on comprehensive empirical research, we prioritised journal articles over conference papers due to their completeness and disciplinary significance.
- After reviewing publishers' websites, 45 relevant academic journals were identified and successfully uploaded into Mendeley.

In the second phase, we turned our attention to popular online media articles, using the keyword "Drone OR UAV AND Malaysia" on Google News. In this phase, the following procedures were implemented:

- A meticulous selection process ensured the inclusion of articles with verified source integrity, clear authorship, minimal topic overlap, and comprehensive coverage of drone technology and its applications in the Malaysian context.
- The selected media articles were imported into Mendeley using the web importer tool, resulting in the addition of 19 articles to the Mendeley library.

3.2 Screening Publication Data

The next step involved a detailed screening of the identified publications to retain only relevant content. This process involved a meticulous examination of both publication details and content, adhering to the following specific criteria:

- Inclusion of publications from 2018 to 2023, covering the most recent five-year period.
- Incorporation of keyword(s) such as UAV or Drone. Limiting these keywords is necessary to define the scope and focus of this study.
- Focus on applications within the Malaysian context. Narrowing the geographical scope to Malaysia was a strategic decision, intended to enhance understanding and guide future developments in the country's drone landscape.
- Validation of authorship.

For the academic papers, the emphasis on journal articles led to the exclusion of three documents, which were primarily reports and research frameworks. Additionally, two documents were excluded due to their unrelated focus: one where the term 'drones' referred to male honeybees, and the other involving oceanic drones (Underwater Vehicles - UUV), whereas this study focused specifically on aerial environments. Furthermore, two more journal articles were omitted as they focused on drone technology developed before the last six years. For media articles, two pieces were removed because they covered similar events. Furthermore, five were excluded for discussing the implications of drones rather than their applications.

As a result, a total of 50 publications—38 academic journals and 12 media articles—meeting the specified criteria were carefully selected (see Figure 1). In the subsequent step, all 50 publications were imported in Endnote XML format to ensure smooth access for Atlas.ti 9 software, facilitating further analysis and exploration of the selected publications. This systematic two-phase approach ensures the acquisition of a selective and diverse dataset, combining both academic and popular writings. This dataset forms the foundation for addressing the first key question of the paper—investigating the patterns and trends characterising the application of drones in recent publications in Malaysia, as previously outlined.

3.3 Expert Interview

Investigating further, we conducted interviews with four experts from two leading local drone companies, Aerodyne Group and OFO Tech. Both companies have harnessed the potential of drone technologies in their business operations and have established strong reputations both locally and internationally (MDEC, 2019). This interview approach aims to provide an added perspective on the current state and potential of drone technologies in Malaysia. The interview questions have been reviewed by an internal panel to ensure their reliability.

To ensure the interviews yielded authoritative insights, stringent criteria were applied in the selection of participants. Each individual nominated for the interview held a higher position

within their respective companies and boasted a minimum of five years of hands-on experience in handling drone technologies. This rigorous selection process aimed to guarantee that the insights derived from the interviews were both credible and informed.

The interview sessions were carefully designed to be explorative, incorporating two open-ended questions that guided the discussion while allowing participants the flexibility to share their unique perspectives and experiences. This method fostered a conversational environment, enabling us to gather rich, nuanced information.

The interviews were recorded with the participants' permission for precise transcription and analysis. A manual audio-to-text conversion process was employed to ensure high precision in capturing the interviewee's responses. The resulting transcription document included sections for speaker identification and interview substance. To enhance accessibility and facilitate broader analysis of the interview data, the content was standardised into English. Only one participant preferred to respond in Bahasa Malaysia, requiring a translation step to ensure linguistic consistency.

To approach saturation in this interview process, we review the transcripts of all interviews, paying close attention to recurring themes, ideas, and patterns in the responses. We then develop a coding scheme to categorise and organise the information, using codes based on key topics, themes, or patterns that emerge from the data. This involves considering any recurring themes or concepts that frequently appear across different interviews. Subsequently, we discuss the findings with peers to validate whether saturation has been achieved, as different perspectives can help confirm if themes have been thoroughly explored.

The final step involves proofreading and cross-checking the transcription data to ensure the accuracy of the participant's responses. The thoroughly reviewed transcripts are then uploaded to Atlas.ti 9 for further analysis and interpretation. This meticulous process aims to provide a reliable and comprehensive exploration of the insights shared during the expert interviews. The analysed insights are subsequently presented in the thematic findings, which will address the second key question of this paper: investigating expert insights to reveal current issues related to the adoption of drone technology in Malaysia, as previously highlighted.

4. THEMATISING DATA

Following Braun and Clark's (2006) approach to thematic analysis, our study incorporated 50 relevant articles and 4 transcripts of expert interviews into Atlas.ti 9, initiating a systematic process. This involved a meticulous reading of the dataset, annotating key points by assigning codes, organising data based on these codes, and discerning overarching themes by exploring correlations between codes. The objective was to uncover meaningful patterns across the dataset.

Atlas.ti 9 served as a powerful platform, aiding researchers in analysis through the creation of networks for linking and triangulating data. By employing this tool, the generated data can be interpreted effectively. The annotation of content with coding enabled the software to process codes, facilitating the documentation of cross-tabulated data. Visualising this interrelation was made possible through tools like the Sankey diagram, providing a graphical representation of complex relationships.

The findings from these relationships address the two main questions posed in this paper. First, the publication analysis of the 50 articles reveals patterns and trends that respond to the initial research question. Following this, thematic investigations examine the current issues surrounding the adaptation of drone technology in Malaysia, drawing on insights from expert interviews. The subsequent sections will explore these aspects in detail.

5. RESULTS AND DISCUSSIONS

5.1 Exploring the Patterns of Drone Applications in Malaysia

This section discusses the findings derived from the publication analysis, addressing the first question of the paper aimed at exploring the prevailing patterns and trends in the current application of drones in Malaysia. Employing a qualitative approach, the study investigates the patterns within academic and online media publications, utilising the Atlas.ti 9 software for thematic exploration.

The process involves categorising and sorting information within specific groups, employing the software to generate a word cloud from 54 documents. This visual representation highlights the most frequently used terms, aiding in the swift comprehension of extensive data. Notably, 'data' emerges as the predominant term followed by 'UAV,' 'image,' 'area,' and 'remote.' This suggests a simplified application of drones for researchers, primarily focusing on acquiring valuable data, particularly images from remote areas. Quantitatively, terms like 'data' and 'image' exhibit high frequencies, with 1,134 and 647 repetitive words, respectively, while 'area' and 'remote' hover around 591 and 511 repetitions. Similarly, terms like 'forest,' 'tree,' and 'model' are prevalent, indicating their association with objects commonly observed in drone applications within the publications.

Furthermore, cross-tabulation data analysis in Atlas.ti 9 reveals publication patterns over the past six years, from 2018 to 2023. It illustrates a positive growth trajectory in drone-related publications. Notably, 2018 witnessed initial publications in academic journals, followed by a surge in the subsequent years, indicating a substantial and growing interest in drone applications among researchers and practitioners.

Figure 2 introduces general themes derived from publications, namely, Transportation; Security, search and Rescue; Monitoring, and Mapping. The analysis indicates consistent relevance of monitoring and mapping applications over six years. Additionally, the diversification of drone applications is evident in transportation and security, search, and rescue, contributing to a wealth of ideas and perspectives in technology innovation.
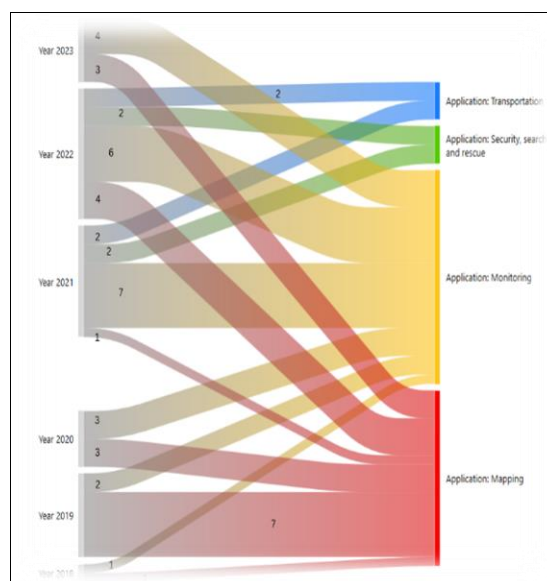

Figure 2. Drone Applications Based on Selected Publications from 2018 to 2023

Over these six years, the agriculture and geoinformation industries dominate the sectors that adopt drone technology. However, a nuanced difference emerges, as the agriculture sector consistently publishes, partly due to the COVID-19 pandemic's response; the geoinformation sector otherwise experiences a decline and halts in 2022. Similarly, the construction and infrastructure sector pause their trend, signaling a need for proactive initiatives to foster drone technology for safety enhancement and operational efficiency.

Figure 3 presents a Sankey diagram illustrating the correlation between drone applications and industrial sectors. The agriculture sector, akin to river management, predominantly adopts drones for monitoring, while the geoinformation sector leans towards mapping. Forestry maintains a balance between mapping and monitoring. This diverse sectoral analysis offers insights for industry experts, encouraging diversification in drone usage to meet challenges and enhance its technological capabilities.
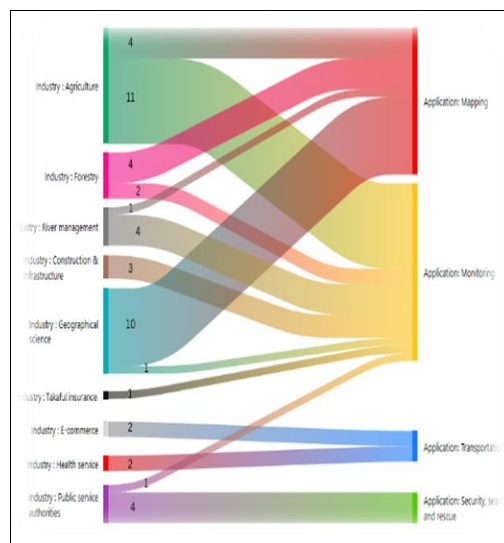

Figure 3. Drone Applications Based on Industry in Malaysia

5.1.1 Recent Trends

The identified patterns pave the way for a thorough discussion on unravelling recent trends in drone applications in Malaysia. Out of 38 academic journal publications, 12 express interest in utilising drones as essential tools for data collection in various fields of study. The recent integration of advanced technologies in drones, such as multispectral sensors (Avtar et al., 2020; Muharam et al., 2021; Muslim et al., 2019; Izzuddin et al., 2020), thermal infrared sensors (Yusof et al., 2022), laser scanning (Kükenbrink et al., 2021), and high-resolution imaging capabilities (Kamarulzaman et al., 2022), has prompted researchers to purposefully deploy drones for acquiring scientific data. Moreover, the adaptable design of drones, capable of integrating various sensors and analysis systems, facilitates the instantaneous capture, visualisation, and analysis of data (Hashim et al., 2023).

Additionally, the availability of diverse software and applications enables drones to autonomously capture photographs, producing dense point clouds for further analysis. This autonomous approach reduces the need for human intervention, facilitating effortless data gathering. In short, the adoption of drones in data collection has become an indispensable tool for researchers, enabling the synthesis of data and promoting innovative strategies to replace conventional methods in their respective fields of study.

5.1.1.1 Monitoring Trend

Drones have revolutionised monitoring across industries by capturing images and videos without physical site access. They have been used for traffic speed monitoring (Sanik et al., 2019), inspecting historical buildings (Yusof et al., 2020), and identifying disaster victims for Takaful insurance (Muhamat et al., 2022). In agriculture, drones assist with disease detection, plant trait analysis, and fertiliser testing, as seen in FELDA's 'Smart Plantation Management Solution' (Aman, 2022). Wireless sensor integration in drones supports environmental monitoring, including river flow predictions (Goudarzi et al., 2022), enhancing disaster preparedness and contributing to sustainable resource management.

5.1.1.2 Digital Mapping Trend

Mapping is a vital technique across various industries, such as agriculture, forestry, and mining. While satellite maps are accessible, drones offer advantages by providing high-resolution, real-time maps. Advanced software now allows for the production of orthophoto images, which include terrain data through Digital Terrain Models (DTM) and Digital Surface Models (DSM). Studies have applied orthophoto mapping for purposes like smart irrigation (Yusof et al., 2022), safety assessments (Ngadiman et al., 2019), and landslide classification (Jamaluddin et al., 2020). Software such as Agisoft Metashape, Pix4Dmapper, and Dronedeploy enable photogrammetry and 3D geometry through point clouds, essential for distance measurement, area calculation, and volume estimation. This technology benefits industries like mining by enabling instant 3D stockpile mapping with lower environmental impact (Sani, 2020). The increasing demand for digital mapping creates opportunities for technopreneurs to develop drone-based photogrammetry solutions, supporting efficient ground surveys and environmentally sustainable operations.

5.1.1.3 Transportation Trend

The versatility and payload capacity of drones makes them advantageous for air transportation, providing unrestricted access to various areas. However, their effectiveness depends on factors such as flight duration and weather conditions for air delivery. While drone adoption in transportation is in its early stages, it holds the potential to decrease road traffic. Overcoming challenges requires dedicated research and development for the commercialisation of drones in transporting items to consumers. Recent media reports showcase e-commerce companies experimenting with drones for delivery, revealing that drone adoption offers cost-effective and environmentally friendly options, particularly with battery-powered drones eliminating carbon footprints (Mardhiah, 2022; Yusof, 2021). Furthermore, local studies focus on utilising drones for medical supply delivery, emphasising cost-effectiveness and the positive impact on healthcare services and the quality of medical products (Zailani et al., 2020; Zailani et al., 2021). In short, the potential for drones to establish themselves in supply transportation necessitates strategies from government bodies for streamlined air regulations and academic research to generate reliable data on digital transportation.

5.1.1.4 Smart Infrastructure Trend

With the government's focus on digital transportation, there is increasing interest in using drone technologies for smart infrastructure development. Aerodyne's first project involved monitoring oil and gas infrastructure at the Rapid Complex, Pengerang, Johor. Academic studies demonstrate drone applications in construction management, such as using Condition Survey Protocol 1 (CSP1) for inspecting historical buildings (Yusof et al., 2020) and university halls (Kaamin et al., 2022). These studies confirm that drones enable immediate defect detection with minimal risk to inspectors, though safety for nearby individuals remains crucial. In public infrastructure, drones have been used to assess the effectiveness of transverse rumble strips on roads by monitoring

vehicle speed (Sanik et al., 2019). Drones provide reliable, naturalistic data as drivers are unaware of their presence. By integrating drones with high-resolution cameras, authorities can efficiently inspect buildings and ensure road safety, reducing operational costs and enhancing safety.

5.1.1.5 Agricultural Trend

Agriculture is vital to Malaysia's economy, necessitating investments in advanced technologies like drones, IoT, and AI for smart farming. These innovations offer the most promising ways to enhance production (Zaman et al., 2023), meeting plantation companies' demands for sustainable, digitised agriculture and ensuring national food security (Aziz, 2023). For example, FELDA has incorporated drone technology into farm management (Aman, 2022), resulting in a surge of articles on smart agriculture, especially in oil palm and rice crops. One pioneering study explored using drones for aerial spraying to control diseases in oil palms (Masri et al., 2022), while others focused on using drone sensors for visual data extraction. Fawcett et al. (2019) used drone imagery to measure palm height in Sarawak, utilising photogrammetry through Structure from Motion (SfM) to create dense point clouds and generate DTMs, presenting an alternative to LiDAR.

Modern drones, equipped with multispectral and hyperspectral cameras, allow farmers to detect subtle plant condition changes. Izzuddin et al. (2020) used multispectral cameras to detect Ganoderma disease, while Avtar et al. (2020) examined multispectral data accuracy across altitudes. In a novel study, Lee et al. (2022) showed that hyperspectral cameras could detect Ganoderma earlier than multispectral ones. Both studies highlighted the efficiency of drone-based data collection for monitoring large plantations. In rice farming, drone integration has garnered interest, with studies analysing farmer acceptance (Azizul, 2023) and specific applications like plant responses to silicon fertiliser (Berahim et al., 2021) and rice plant trait estimation (Muharam et al., 2021). During the COVID-19 pandemic, drones proved crucial in sustaining agriculture amid labour shortages, reducing reliance on forced labour (Ibrahim, 2022; Shu, 2021), demonstrating the resilience and cost-saving benefits of smart farming.

5.1.1.6 Forestry Trend

The use of satellite data and aerial photographs has significantly improved forest ecosystem management. Drones offer a cost-effective and accurate alternative to traditional satellite monitoring, as demonstrated by Ruwaimana et al. (2018). This has led to the integration of drone technology in forest management, including studies on light extinction (Kükenbrink et al., 2021) and mangrove tree height measurement (Saliu et al., 2021). Saliu et al. (2021) achieved high accuracy by combining drones with a Leica densitometer, while Kükenbrink et al. (2021) used drone-equipped laser scanning for canopy measurements in temperate forests.

Further research has focused on logging activities and forest preservation. Kamarulzaman et al. (2022) identified forest gaps and classified logging impacts, while Siti-Nor-Maizah et al. (2022) examined emission factors. Both studies used orthomosaics from Agisoft Metashape and combined drones with satellite data for accuracy validation. Overall, the integration of drones and satellite information proves to be a reliable approach for monitoring selective logging impacts and emission effects.

5.1.1.7 Geo-informatics Trend

In the context of geo-informatics trends, it illustrates the use of drones alongside remote sensing technology to acquire updated, high-resolution images for geo-information mapping. These images are subsequently processed using Geographic Information System (GIS) tools to facilitate

fundamental geographic analysis for decision-support management. The integration of drone technology enables the creation of models that can evaluate the impacts of various alternative decisions.

Five articles have conducted drone operations to derive geoinformation data through aerial imaging. In a foundational study conducted by Lowe et al. (2019), drones were employed to derive orthomosaic and DSM data for assessing changes in island shorelines through volumetric measurements. Advancements in technology have allowed the integration of satellite technology with drone-captured images, enabling the determination of Earth element boundaries (Mohamed et al., 2019), characterisation of stratified features (Hassan, 2021), and documentation of the unique architecture of Malay cities (Noor et al., 2019; Noor et al., 2020). Mohamed et al. (2019) manually examined aerial images to determine the geomorphological features' boundaries on Ular Island, Langkawi for mapping. Subsequent studies enhanced mapping techniques by introducing point cloud processing for digital photogrammetry, allowing the scanning of Malaysia's heritage buildings in Kota Bharu, Kelantan (Noor et al., 2019), and collecting stratified data on Sanai Hill, Perlis (Hassan, 2021). Within a year, Noor et al. (2020) further improved mapping techniques by incorporating mobile laser scanning, UAV, and satellite data.

Rivers, crucial water sources requiring preservation, have been the focus of numerous studies utilising drones. Elijah et al. (2018) monitored river water quality through smart monitoring, integrating drones with the IoT, Low Power Wide Area (LPWA), and data analytics for effective real-time monitoring of temperature and pH levels. Geraeds et al. (2019) assessed plastic debris, while Ansari et al. (2021) used image processing to segment flow zones and plant growth, enhancing river management for future planning. Local studies have explored drone technology applications in hydro-morphology studies. Muslim et al. (2019) addressed sun glint effects on coral-reef mapping, correcting images through image processing to produce reliable coral maps for marine ecology. Another study by Mohamad et al. (2019) focused on river studies using drones and Global Navigation Satellite System (GNSS) vertical data to monitor changing water levels. Employing the SfM algorithm for photogrammetric processing, the study generated DSM and orthomosaic data, enabling the measurement of water levels at different tidal phases. The combination of drones and GNSS vertical data proves crucial in preserving water resources by mapping aquatic species and monitoring river water levels.

5.1.1.8 Search and Rescue Operations Trend

Drones have proven highly effective in various sectors, particularly in Search and Rescue (SAR) missions due to their capabilities and reach. Khamseah (2022) emphasises that drones are vital in SAR operations, reducing human risks, speeding up searches, and providing aerial support in adverse weather. This is especially important in Malaysia, where monsoon-related floods occur annually, making drones crucial for public safety tasks such as guiding victims, delivering supplies, and assessing damage (Yusof, 2022).

In civil safety, drones equipped with high-resolution cameras assist law enforcement in tracking criminals and addressing border security threats. An expert interview noted an annual economic loss of about 8 billion due to border issues. Additionally, drones play a crucial role in ensuring public safety during pandemics by monitoring crowds (Nordin, 2022; Ratcliff, 2021). In short, drones enhance national resilience to external crises and expedite recovery through their strategic use in safety and security operations.

5.1.1.9 Healthcare Trend

Within healthcare services, drones play a crucial role in supplanting traditional ambulances for transporting medical items, leveraging their mobility advantages. Ensuring safety and cost efficiency becomes paramount in the establishment of commercial air transportation, necessitating extensive research and development. To this end, studies have been conducted to evaluate the effectiveness, economy, and durability of drones in medical transportation.

In an initial study, Zailani et al. (2021) conducted a comparison to assess the cost-effectiveness of transporting blood products between drones and ambulances. Building on this groundwork, Zailani et al. (2022) expanded the research to evaluate the quality of transported materials and blood samples under tropical climates. Both studies affirmed the promising potential of using drones for blood transportation to any geographic area at a reasonable cost. Notably, the quality of blood products remained satisfactory and safe in tropical climates when transported using a carriage made from Expanded Polystyrene (EPS). The studies further emphasised that drones offer a more practical and cost-effective means of transferring blood supplies during emergencies.

5.1.1.10 Civil Service Trend

Building upon the prior strides in the integration of drones within public healthcare, the trend has gained further traction within the civil service. As highlighted in various articles, the focus now extends to exploring the myriad applications of drones in law enforcement and search and rescue departments, thereby playing a pivotal role in enhancing public safety and security. Notably, drone technology's advantages in terms of manoeuvrability make it a valuable asset in crisis management scenarios, particularly during flood events (Dzulkifly, 2021). Law enforcement bodies emphasise the utilisation of drones to enhance safety measures, including improvements in border access (Dzulkifly, 2021), identification of individuals with elevated body temperatures (Ratcliffe, 2021), and enforcement of pandemic-related regulations (Nordin, 2022). These utilisations underscore the multifaceted applications of drones in law enforcement, emphasising their role in addressing diverse challenges.

Concurrently, the search and rescue department's perspective is exemplified by an article highlighting the use of drones during recent flood disasters in Pahang and Selangor states (Yusof, 2022). According to this article, the establishment of the Special Drone Services Emergency Task Force (PTK2Dron) demonstrated the swift response capabilities of drones in mitigating the impact of flood disasters.

The publication analysis unveils distinct patterns and trends in the application of drones within the Malaysian context. To delve deeper into this realm, we conducted an expert interview aimed at providing a contextual understanding of the prevailing issues associated with the adoption of drone technologies, which will be the focus of the next section.

5.2 Current Issues in the Adaptation of Drone Technology in Malaysia

A thematic analysis was conducted on the expert interview, yielding 35 codes from the 1,793-word transcripts. These codes were subsequently categorised into 4 clusters based on their similarities. The data derived from the interview was illustrated (in Figure 4), and the patterns of themes were rigorously scrutinised against the two aspects of the interview questions.
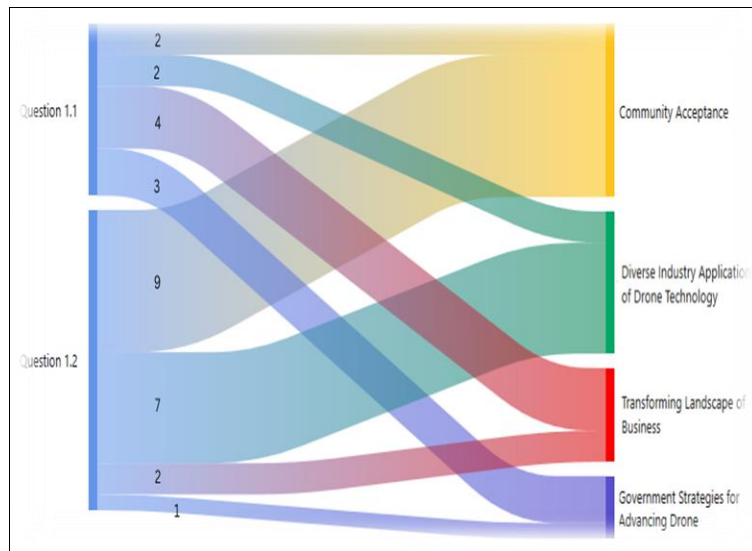
Figure 4. Four Clusters Derived from the Two Aspects of the Interview Questions

The cluster of 'Community Acceptance' emerged as the most prevalent, supported by 11 codes from the interviews that delved into the current state of drone technology in Malaysia. Following closely was the cluster of 'Diverse Industry Applications of Drone Technology.' Upon deeper examination, (Figure 5) reveals 35 codes identified from the four interview participants. The theme 'Diverse Industry Applications of Drone Technology' has the highest number of codes, specifically 11 codes; however, it remains less covered compared to other themes due to the lower density of each code. Meanwhile, the code 'Introducing Policy Making' is the most prominent, with significant discussion among the participants falling under the theme 'Government Strategies in Advancing Drone.' As a result, it contributes the largest area to its theme, followed by 'Community Interest' and 'Establishing a Sustainable Ecosystem,' both of which are under different themes.
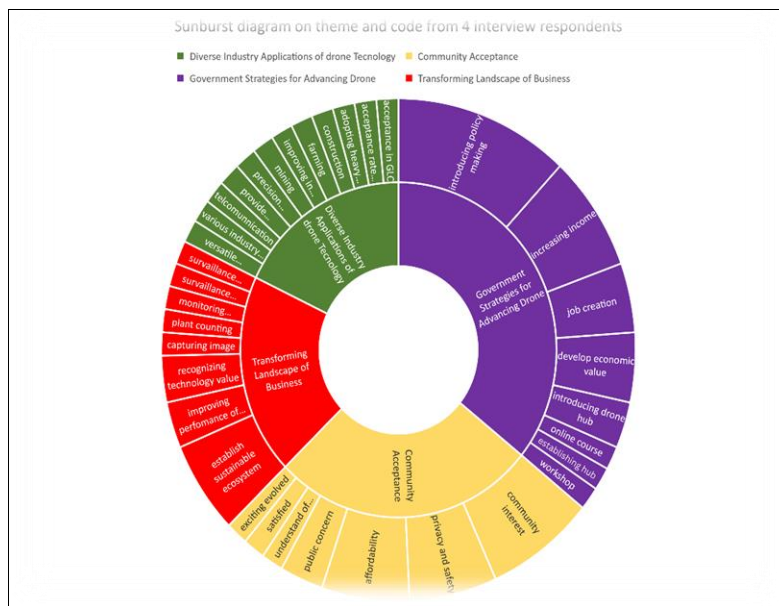

Figure 5. The Sunburst Diagram on Theme and Code Identified from the Responses of the Four Interview Participants

5.2.1 Theme 1: Community Acceptance

The exploration of drone technology development in Malaysia reveals community acceptance as a pivotal theme. In the dynamic landscape of technological progress shaping society, understanding how the community embraces innovation becomes crucial. The concept of acceptance unfolds through two interconnected dimensions: community interest, public concern, and government imitative.

Concerning community interest, the emergence of drone technologies has ignited substantial enthusiasm across diverse segments of the Malaysian community, as highlighted in interviews. From educational institutions incorporating drone-related modules to local tech enthusiasts and start-ups exploring innovative applications, a clear passion surrounds the potential of these aerial devices. This heightened community interest underscores the acknowledgment of drones not merely as transient gadgets, but as transformative tools poised to redefine various sectors. Expert interviews portray a burgeoning ecosystem where local talents, academia, and businesses converge to leverage the multifaceted capabilities of drones. This collective momentum signifies a nation ready to embrace and lead in the realm of drone technology.

On the topic of public concern, however, innovation brings with it a responsibility, and the rapid rise of drone technologies has not been immune to apprehensions. Public concern, derived from expert discussions, centers on issues of privacy, safety, and ethical use. As drones become more integrated into daily life, pertinent questions arise: How will drones impact personal privacy, especially in densely populated areas? Are there adequate regulations to prevent misuse? How do we ensure that drones, while beneficial, do not compromise societal values? These concerns reflect a community that is not only enthusiastic but also discerning and conscious of the broader implications of technological advancements. In this context, engaging with the community and fostering an understanding of drone technology through educational initiatives is crucial for establishing clear regulations to address privacy and safety concerns.

The narrative of drone technologies in Malaysia, viewed through the lens of community acceptance, evolves as a story of optimism entwined with caution. While there is undeniable excitement about the transformative potential of drones, there exists a collective awareness of the challenges they pose. This emphasises, as recommended by experts, the need for thoughtful navigation in their integration into society.

5.2.2 Theme 2: Diverse Industry Applications of Drone Technology

The remarkable versatility and capabilities of drone technologies have ignited widespread interest across diverse industries, positioning them as remarkable tools for a myriad of applications. In Malaysia's pursuit of technological progress, the integration of drones into various sectors emerges as a prominent and impactful trend. In harnessing drone technology across industries, this section explores the expansive realm of drone applications in Malaysia, distinctly categorised into industries' acceptance and multifaceted sector applications.

Regarding industries' acceptance, the assimilation of drone technologies goes beyond a mere acknowledgment of their potential; it signifies industries' proactiveness in embracing innovation. Insights from expert interviews reveal a growing openness among Malaysian industries towards the manifold benefits that drones bring. From operational streamlining to the introduction of cost-effective solutions, drones are increasingly recognised as invaluable assets. This acceptance is further reinforced by industry leaders and policymakers who acknowledge the competitive advantage that drone integration can provide. The rise in the number of workshops, training programmes, and collaborative projects centred on drones' underscores industries actively seeking to leverage their capabilities. For example, the Malaysia Technology Development

Corporation (MTDC) has signed a Memorandum of Understanding (MoU) with Agrobank to offer training for agricultural entrepreneurs, aiming to integrate smart farming practices aligned with Industry Revolution 4.0 (Bernama, 2021). This targeted modern agricultural training programme demonstrates the potential of drones to enhance technopreneurship within the agricultural sector.

Concerning multifaceted sector applications, the adaptability of drones is vividly illustrated by their pervasive applications across diverse sectors in Malaysia, as also evident from the publication analysis. In agriculture, drones are employed for precision farming, enabling targeted treatments and efficient monitoring. Within the construction and real estate realms, drones offer aerial surveys, facilitating comprehensive site analyses and real-time project monitoring. The entertainment sector, too, capitalises on drones for cinematography, providing novel perspectives and elevating production values, as highlighted by participants. Expert interviews underscore the myriad ways in which drones are being harnessed, reflecting their multifunctional nature and the innovation-driven ethos of various sectors in Malaysia.

5.2.3 Theme 3: Transforming the Landscape of Business

Drones, equipped with advanced aerial capabilities and a diverse range of sensors, stand as unparalleled tools for versatile data collection. As discussed earlier, across various industries, spanning agriculture to real estate, drones offer access to hard-to-reach areas, capture high-resolution imagery, and provide real-time feedback. This unprecedented versatility is transforming the landscape of data-gathering practices in businesses. Where traditional methods may have been time-consuming, resource-intensive, or even infeasible, drones provide a quick, efficient, and comprehensive solution. Expert interviews consistently highlight the growing dependence on drones for tasks like land surveys, crop monitoring, and infrastructure inspections, showcasing their transformative impact on data collection methodologies. This theme of versatility is explored through two key aspects: advancing data processing and improving performance.

In advancing data processing, beyond mere data collection, the integration of drone technology is revolutionising how businesses process and interpret data. Utilising advanced analytics tools and fluid software integrations, data captured by drones can be swiftly processed to generate actionable insights. Whether employing thermal imaging to detect infrastructure anomalies or utilising AI-driven algorithms for agricultural health analysis, drones are at the forefront of advancing data analytics. Expert insights affirm that businesses are not only streamlining operations but also gaining deeper insights, enabling proactive decision-making and the formulation of predictive strategies.

Regarding improving performance, at the heart of business transformation lies performance enhancement, and drones play a critical role in this realm. Through real-time monitoring, reduced operational costs, and provision of accurate data, drones are elevating the operational efficiency of businesses. Furthermore, their contribution to enhancing safety, particularly by minimising human intervention in hazardous areas, is noteworthy. Expert interviews illustrate numerous instances where the introduction of drones has resulted in faster project completions, reduced overheads, and improved safety records, highlighting their value in driving business performance. Therefore, it is crucial to promote investment in drone technology and data processing, while also offering incentives to local companies for adopting and integrating drones into their business operations.

5.2.4 Theme 4: Government Strategies for Advancing Drone

As the potential of drone technology becomes increasingly apparent, government initiatives play a pivotal role in fostering its growth, ensuring ethical use, and maximising societal benefits. This

theme sheds light on the Malaysian government's proactive efforts to mould the drone technology landscape, examined through two key dimensions: establishing drone programmes and developing economic values.

Government-backed initiatives are crucial for establishing drone programmes, and promoting the development and adoption of drone technologies. These initiatives include research and development grants and training programmes. Expert interviews highlight the Malaysian government's proactive approach to creating dedicated programmes that foster technological innovation while ensuring the safe use of drones. Initiatives may feature pilot training, drone tech incubators, and collaborations between academic institutions and industry leaders. This reflects the government's recognition of drones' transformative potential and its commitment to fostering a supportive environment for their growth.

On the development of economic values, beyond the technological facet, the economic implications of drone technologies are profound, making the government's role crucial. By introducing incentives for drone start-ups, facilitating investments, and positioning Malaysia as a hub for drone innovation, the government actively works toward deriving economic value from this burgeoning sector. Expert interviews emphasise the numerous opportunities being created, such as jobs, new business ventures, and increased exports. Furthermore, by integrating drone technologies into sectors like agriculture, logistics, and infrastructure, there is a multiplier effect on economic value, driving efficiency and reducing costs across the board. To capitalise on these benefits, it is important to strengthen government initiatives and incentives that support the development and responsible use of drones. Encouraging collaboration between government, academia, and industry will further foster innovation and drive economic growth in the drone sector.

Overall, the development of drone technologies in Malaysia is a combination of enthusiasm, strategy, and governance. Each theme, while distinct, interweaves with the others, creating a comprehensive narrative of a nation poised to harness the full potential of drone technologies. The insights from the interviews present a promising trajectory for drones in Malaysia, shaped by collaboration, innovation, and a deep-rooted commitment to societal and economic growth.

6. CONCLUSION

The paper discussed a comprehensive thematic review by evaluating and synthesising existing perspectives related to the utilisation of drones in Malaysia. Our investigation encompassed a publication analysis of academic journal papers and media articles published between 2018 and 2023, coupled with insights garnered from expert interviews. Employing a systematic approach to code identification and tabulation, we meticulously developed themes for data analysis, focusing on the application of drone technology and its adoption trends. The review was framed around two pivotal questions as we observed burgeoning interest in the discourse surrounding drone technologies in Malaysia.

Beginning in 2018, the integration of drones has exhibited a consistent and escalating presence in various industrial sectors, notably in infrastructure, transportation, agriculture, healthcare, and public services. This burgeoning trend underscores the versatility of drones, which are now employed for diverse operations such as monitoring, mapping, and search and rescue missions. In these regards, numerous exploratory projects and programmes have been instigated at both governmental and community levels, amplifying the crucial role of drones for localised benefits. Expanding on our findings, the evolution of drone technologies has emphasised the importance of integrated data performance and digitalisation across a spectrum of industrial sectors. The multifaceted applications of drones have demonstrated their potential to revolutionise

traditional processes, enhance efficiency, and contribute to data-driven decision-making. Concurrently, the issue of community acceptance emerges as a critical challenge in the integration of drone economies within the broader societal framework in Malaysia. As we explore the nuanced landscape of drone implementation, it becomes evident that technological advancements are not merely confined to a singular sector but have far-reaching implications for the overall socio-economic fabric. The collaborative efforts between government initiatives and community-driven projects highlight the collective recognition of drones as transformative tools with the capacity to address diverse challenges and unlock new possibilities.

This study is confined by the scope of selected publication analysis and interview participants. Nevertheless, the uncovered findings from the study introduce a novel avenue for exploring the role of drones within the broader Malaysian-built environmental landscape. We aim to enhance our methodological approach by incorporating a wider range of perspectives from diverse participant backgrounds, including economists, engineers, policymakers, and government agencies. This inclusive approach will contribute to an expanded understanding of the potential applications of drone technologies in Malaysia, surpassing current paradigms. Furthermore, an exploration of the intricate relationship between emerging drone technology and the burgeoning digital gig economy could provide additional insights into this matter. By delving into this specific aspect, we anticipate uncovering valuable perspectives that will enrich our understanding of the evolving dynamics between drone technology and its impact on the built environment and socio-economics of Malaysia.

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