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Green Warehouse Practice: Critical issues in drone technology adoption

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Abstract
Businesses are being revolutionised by drones, which are now used in a variety of sectors, including warehouse operations. Drones are portable, highly manoeuvrable, and have both indoor and outdoor flight capabilities. Drones assist in streamlining the overall inventory management process for monitoring and inspection in support of green warehousing practices (GWP). Although the use of drone technology is rapidly expanding and is trending upward, relatively few studies on the subject have been published and there is a great need for scholarly study in this field. Thus, this study aims to identify several issues faced by warehouse operators.

Keywords: Green Warehouse Practice, Drone Technology, Adoption, Issues

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1.0 Introduction

Drones, sometimes known as unmanned aerial vehicles (UAVs) are powered aerial vehicles without a human pilot that uses aerodynamic forces to lift the vehicle. According to the current trend, drones are anticipated to be quickly absorbed into a variety of sectors and parts of our daily lives. A drone is able to execute a wide range of capabilities, including diving underwater for a particular underwater task and delivering packages (Nier et al., 2020; Otto et al., 2018). For instance, Amazon Prime Air started using drones to deliver small packages. Similar to FedEx, UPS Flight Forward, and DHL Parcelcopter, these large businesses use drones to deliver packages and food (Emergenresearch, 2022). Additionally, businesses like Amazon, Wal-Mart, and the Workhorse Group use drones for inventory management to enhance customer experiences and optimise warehouse operations in general (Ingles, 2016). From the local perspective, Northport is the first port in Malaysia to deploy a closed-circuit surveillance system that integrates drones to improve the safety and security of the port. It is also part of the company's Health, Safety and Environment (HSE) excellence by embarking on 'Sustenance and Continuous Improvement' to strengthen the best HSE practices among their stakeholders (Anis, 2016).

Drone technology has become widely used in a variety of industries, including warehouse operations. Drones are used by warehouse operators to boost output, improve stock control and reliability, boost safety and cut costs. Drones are frequently used in warehouses to

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perform inventory audits and cycle counts. Due to their high productivity, fast speed and great precision (up to 97-99%), drones can be used more frequently than manual labour (Nier et al., 2020). Moreover, since flying a drone requires little to no skill, it is simple to adopt. It can also operate remotely or when the drone is in view, which requires fewer resources. Additionally, drones provide a safer atmosphere and eliminate the need for moving things (Puliti et al., 2021). Drones have begun to simplify and change the warehouse operating landscape. Hence, the adoption of drones will significantly alter the entire warehouse operation.

Given all of its benefits, its application will likely become more widespread in the future. Despite this, the warehouse operators encountered a few issues when adopting drone technology. For instance, a new technology's adoption becomes challenging when the present warehouse management system (WMS) is incompatible with the new technology. The issue of sloppy storage presents challenges for warehouse operators as well. When goods protrude from pallets or barcode tags tear or cut from carton edges, the drone is unable to detect them, thus necessitating human intervention (Nier et al., 2022). Additionally, drone technology cannot scan the entire pallet on the shelf and is only capable of scanning one deep storage and the drone can only scan the racking's front face. Thus, the warehouse operator must work together with the drone technology provider and consider how to redesign the racking system in light of this. Another issue with drone technology adoption is the limited flight time caused by battery life. Furthermore, stakeholders have little interest in drone technology adoption due to the lack of awareness that prevents its deployment. Besides, security, public reactions, and government regulation issues are some of the key obstacles to its adoption (Yahya et al., 2021; Haini et al., 2019). Therefore, the primary objective of this study is to investigate the foremost issues to drone technology adoption among Malaysian warehouse operations in realising the GWP.

2.0 Literature Review

2.1. Drone Technology

Drones are portable, highly manoeuvrable, and have both indoor and outdoor flight capabilities (Castro et al., 2021). The degree of autonomy, size, and weight of the various types of drones can be used to distinguish their functionality. A few drones are operated by humans, but most are operated autonomously. Iqbal (2021) claims that the drone uses the global positioning system (GPS) and checks the telemetry at the ground control station (GCS). Drones must be operated within line of sight and within the operator's line of sight in accordance with the Federal Aviation Administration (FAA) regulations. Unmanned ground vehicles (UGV) like autonomous self-driving cars, unmanned surface vehicles (USV) for surface water operation, and autonomous underwater vehicles are some drone technology examples. UAVs include multirotor or quadcopters, unmanned combat aerial vehicles (UCAV), and unmanned spacecraft both remote-controlled and autonomous (Companik et al., 2018).

2.2. Green Warehouse Practice

For many years, scholars and researchers have concentrated on the requirements of a green approach, in particular, green warehousing practices (GWP). GWP are essential for the logistics sector because of mounting demand and environmental concern over carbon footprint. The number of warehouse infrastructures has gradually expanded over time due to the important role that warehouses play in the logistics industry. There would be a significant negative impact on the environment if green practices are not in place (Azmin et al., 2015). Shorter response times, higher productivity and a decrease in inventory are the main advantages of GWP. Moreover, GWP literature is still few and scarce despite the growing interest in GWP among academics and practitioners. Barcoding, radio frequency identification (RFID), electronic data exchange (EDI), robotics and drone technology are just a few of the cutting-edge technologies that GWP depends on. Having a predicted CAGR of 13.2% from 2021 to 2030, the worldwide warehouse robotics market, which had a value of $4,400 million in 2020, is expected to reach $15,792 million by 2030 (Azmin et al., 2015; Placek, 2022).

For larger businesses looking for a competitive edge in a time of labour shortages and extremely demanding customers, warehouse robotics has transitioned from novelty to mainstream. Warehouse operators are more concerned and committed to enhancing warehousing operations and functions as a result of the growing need to reduce costs and carbon footprints (Johar et al., 2014; Wahab et al., 2018). This makes sense given that the infrastructures and operations associated with warehousing are among the vital components due to the environmental effect caused by warehousing operations has increased. Thus, the possibility of lowering carbon emissions by implementing GWP is deemed essential not just to lower carbon emissions per se, but it may also have positive effects on the economy and society at both the micro and macro levels (Xin et al., 2019). Therefore, the current research is essential to investigate drone technology adoption as part of the GWP initiatives.

2.3. Drone Technology Adoption in Warehouse Operations

Drone technology adoption could significantly enhance overall warehouse operations. For instance, inventory management using bar codes, RFID and QR codes in conjunction with the Internet of Things (IoT) is made easier by drones. Inventory auditing by drones eliminates the majority of the requirement for physical employees to climb warehouse racks and carry out other hazardous tasks (Shibghatullah et al., 2022). Likewise, drones provide high-quality video that helps monitor vermin, monitoring temperature-controlled items, sighted objects in the dark and spotting indicators of broken wiring or leaking roofs. Additionally, drones might offer auditability information like RFID, geo-locational and other sensor data. Drones thus possess the potential to significantly increase the efficiency and efficacy of inventory and facility management towards GWP.

3.0 Methodology

Given the lack of knowledge regarding the issues in implementing drone technology, particularly in warehouse operations, this study is exploratory in nature. Since there have not been many studies on the adoption of drone technology, it is regarded as important to undertake qualitative research in which information is gathered through a series of focus groups and interviews. Purposive sampling and judgement sampling are used in this study because the information from certain target groups is easily accessible. Focus groups are frequently used in exploratory studies and in the discovery of new phenomena. Additionally, focus groups enable open, spontaneous, free-flow and in-depth conversation among the groups, enabling larger inputs (Sekaran & Bougie, 2009) in eliciting more issues with the implementation of drone technology.

The researcher serves as the focus group's moderator and acts to introduce the topic, pose the questions, observe, record the conversation and take notes. To more thoroughly analyse the conversation, the conversation needs to be recorded and transcribed. The use of unstructured interviews allows for the identification of a series of crucial issues that may be at the centre of the larger issues in this study (de la Croix et al., 2018). Although there are limited studies on the use of drone technology in warehouse operations, the interview questions were created by combining important data from the literature on warehouses and related drone topics. This is done to ensure that the study addresses pertinent and significant concerns and is able to establish its validity.

Focus groups should comprise six to ten responders as recommended by Bell et al. (2022). The focus group's main theme is critical issues in drone technology adoption. To encourage transparency and prevent bias, all the questions are created and grouped from broad to specialised (Grudens-Schuck, 2004). Data is transcribed and evaluated and conclusions are drawn once all the conversation is recorded and relevant information is collected from the focus group (Bell et al., 2022). All the recommended respondents have extensive expertise in drone technology, warehouse operations and hold respectable positions in their respective firms. Accordingly, the respondents for this focus group consisted of eight experts as summarised in Table 1.

Table 1. List of experts

Company	*Nature of Business*	*Designation*	*Experiences (years)*
MY1	Warehousing and fulfilment	Senior Manager	> 13
MY2	Warehousing	Co-Founder & CEO	> 23
MY3	Warehousing and logistics	Senior Team Leader	> 24
MY4	Total logistics	Chief Operating Officer	> 17
MY5	Warehousing and logistics	Senior Manager	> 16
MY6	Cold chain logistics	Managing Director	> 13
MY7	3PL warehousing	Operations Manager	> 18
MY8	3PL provider	Operations Team Leader	> 19

Note. Names of the experts and organisations are not revealed as per anonymity commitment

4.0 Findings and Discussion

The expert's focus group issues were recorded and compared. Any repeating issues were crossed off from the final lists. The issues with drone technology adoption are listed in Table 2. All issues are coded with the ISSUE #.

Table 2. Drone technology adoption issues

Code	*Issues Encountered*
ISSUE 1	Familiarity issues
ISSUE 2	Adaptability issues
ISSUE 3	Privacy issues
ISSUE 4	Security issues
ISSUE 5	Safety issues
ISSUE 6	Reluctant to change from conventional practice
ISSUE 7	Lack of knowledge about drone technology values and benefits
ISSUE 8	Lack of expertise in drone operations know-how
ISSUE 9	Lack of promotion and understanding
ISSUE 10	Lack of drone operations guidelines
ISSUE 11	Lack of communication between the government, drone technology companies and warehouse operators
ISSUE 12	Lack of integration between drone providers and warehouse operators
ISSUE 13	Lack of information on drone technology and practices
ISSUE 14	Lack of 5G network technology
ISSUE 15	Absent in successful drone adoption as benchmarking
ISSUE 16	Unclear government regulations, policies and intervention
ISSUE 17	Limited drone battery life
ISSUE 18	Vulnerability to damage (sensitive)
ISSUE 19	Complexity (issue with barcode stickers tearing or cut)
ISSUE 20	Different procedures practised by different warehouse operators
ISSUE 21	Limited technical capability
ISSUE 22	High initial investment
ISSUE 23	Limited drone size for various inventory types (for loose inventory-picking activities)
ISSUE 24	Limited drone technology training and education
ISSUE 25	Absence of a drone technology ecosystem
ISSUE 26	Lack of system integration (WMS)
ISSUE 27	Limited to single deep scanning (only can scan the front face of racking)

The issues with drone technology adoption are divided into five clusters based on the similarities between the issues as displayed in Table 3. The first cluster, BARRIER 1, is made up of ISSUE 2, 6, 7, 9, 15, and 27, which represent absorptive capability issues such as adaptability and expertise issues. ISSUE 12, 13, 20 and 26 are clusters in BARRIER 2 that postulates the stakeholder's integration and collaboration issues among warehouse providers including lack of information and system integration issues.

Issues concerning the technological infrastructure are labelled BARRIER 3 with seven issues (ISSUE 1, 3, 4, 5, 14, 17 and 19). The fourth cluster categorized as BARRIER 4 concerns government support and promotion of drone technology adoption in warehouse operations. Around six issues in this cluster are ISSUE 9, 10, 11, 16, 24 and 24. Finally, BARRIER 5 is labelled perceived cost that indicates the high initial investment in drone technology adoption among warehouse operations (ISSUE 18, 21, 22 and 23).

Table 3. Issues in drone technology adoption clusters

Cluster	*Issues Encountered*	*Code*
BARRIER 1: Absorptive capability	Adaptability issues	ISSUE 2
	Reluctant to change from conventional practice	ISSUE 6
	Lack of knowledge about drone technology values and benefits	ISSUE 7
	Lack of expertise in drone operations know-how	ISSUE 8
	Absent in successful drone adoption as benchmarking	ISSUE 15
BARRIER 2: Stakeholder's integration and collaboration	Lack of integration between drone providers and warehouse operators	ISSUE 12
	Lack of information on drone technology and practices	ISSUE 13
	Different procedures practised by different warehouse operators	ISSUE 20
	Lack of system integration (WMS)	ISSUE 26
	Limited to single deep scanning (only can scan the front face of racking)	ISSUE 27
BARRIER 3: Technological infrastructure	Familiarity issues	ISSUE 1
	Privacy issues	ISSUE 3
	Security issues	ISSUE 4
	Safety issues	ISSUE 5
	Lack of 5G network technology	ISSUE 14
	Limited drone battery life	ISSUE 17
	Complexity (issue with barcode stickers tearing or cut)	ISSUE 19
BARRIER 4: Government support and promotion	Lack of promotion and understanding	ISSUE 9
	Lack of drone operations guidelines	ISSUE 10
	Lack of communication between the government, drone technology companies and warehouse operators	ISSUE 11
	Unclear government regulations, policies and intervention	ISSUE 16
	Limited drone technology training and education	ISSUE 24
	Absence of a drone technology ecosystem	ISSUE 25
BARRIER 5: Perceived cost	Vulnerability to damage (sensitive)	ISSUE 18
	Limited technical capability	ISSUE 21
	High initial investment	ISSUE 22
	Limited drone size for various inventory types (for loose inventory-picking activities)	ISSUE 23

BARRIER 1 indicates the absorptive capability issues encountered in the new technology adoption which is in line with Lorenz et al. (2022) study where firms faced difficulties in adopting new technology due to a lack of knowledge. This study found that knowledge about drone technology values and benefits is limited due to a lack of awareness. Thus, for warehouse operators to successfully adopt drone technology, expertise in drone operations know-how, drone adoption benchmarking, and change in mindset is imperative. This is also articulated by the experts from MY2 Company and MY7 Company as warehouse operators are facing a hard time adopting drone technology since the resources is not fully ready to accept and adopt the new technology including drones. All experts agreed that drone technology adoption in Malaysia is still in the infancy stage and there are none of the warehouse operators can claim that they are a model for successfully adopting drone technology. This is because the majority of warehouse operators still lack the professionals and knowledge in adopting drone technology.

Moving forward, BARRIER 2 discusses the stakeholder integration and collaboration issue. The Managing Director of MY6 company stressed that the major issue is there is no integration between drone providers, government agencies and warehouse operators themselves. Different drone providers apply dissimilar practices and procedures and this situation will lead to unstandardised information on drone technology adoption and practices. Additionally, an expert from MY1 company stressed having proper WMS integration with drone technology and the need of overcoming the issue of single deep scanning as a solution to enhance its adoption. The situation depicted by MY5 Company is in line with the views of MY8 Company and is also supported by Puliti et al. (2021). Therefore, stakeholders' integration and collaboration are important to build collaborative partnerships to pool knowledge, expertise and experience to co-create solutions for better drone technology adoption in gaining a competitive advantage (Haini et al., 2019).

Next, BARRIER 3 specifies the technological infrastructure issue. The unfamiliarity with drone technology due to lack of awareness is the main issue that hinders the new technology's adoption. Most of the stakeholders are also very concerned about privacy and security issue. For instance, Company MY3 claimed that they were very concerned about the types of data that drones will gather in both public and private spaces, and in what way that data is kept and distributed. Likewise, the safety issue is another concern whereby warehouse operator is very concerned about data protection against safety threats as well as the safety of manpower such as drones falling high and hitting employees (Iqbal, 2021). Alike, MY4 Company CEOs emphasized that not all warehouse operators can afford to face these issues as it will involve extensive investment. Comparable, experts from MY2 Company and MY4 Company revealed the current situation of unstable 5G network technology and limited drone battery life making its adoption become complex.

BARRIER 4 expresses the issues about the government's support and promotion. Even though the researcher's opinion may conflict

with this issue, experts still see it as an issue. MY3 Company, MY6 Company and MY7 Company featured that the unclear government regulations, policies and intervention in promoting drone technology in warehouse operations are the main cause of its slow adoption. Moreover, it is discouraging that the stakeholders do not understand the values and importance of drone technology adoption in warehouse operations (Johar et al., 2014). Furthermore, it is a need to educate and train the warehouse operator about drone technology success stories. This is because, some of the warehouse operators deemed training for drone technology organized by drone authorities to be inadequate, irrelevant or not progressive to their nature of business. Thus, a clear drone technology ecosystem is needed to ensure all stakeholders understand its applicability and how it may benefit the industry.

Lastly, BARRIER 5 covers the perceived cost issues and perception of adopting drone technology. MY5 Company stressed that, although GWP is their main priority, drone technology adoption is not part of their plan. This is due to the limited technical capability, vulnerability to damage and high maintenance cost which MY1 Company agrees that conventional warehouse operations are still relevant. In addition, expanding GWP into drone technology adoption will entail substantial investment that will be considered tough to cater to. MY5 Company expert states that vulnerability to damage is a burden to them in adopting drone technology. Running conventional warehouse operations already necessitates huge capital spending and investment, and adding drone technology will have a significant financial impact (Xin et al., 2019). Moreover, all experts agreed that the awareness and mindset that drone technology adds more cost because required different software, running separate warehouse facilities and different use of handling equipment will ultimately affect the overall warehouse costs. These negative perceptions of adopting drone technology are observed as an issue among the stakeholders. Plus, limited drone size for various inventory types also has a negative impact on its overall adoption.

5.0 Conclusion and Research Directions

As a result, it can be said that the adoption of drone technology is plagued by five primary issues namely absorptive capability (BARRIER 1), stakeholder integration and collaboration issues (BARRIER 2), technological infrastructure (BARRIER 3), government support and promotion (BARRIER 4) and perceived cost (BARRIER 5). These concerns raise the possibility of further research into the barriers and critical success factors in adopting drone technology into warehouse operations. The issues identified in this study can also be connected to the technological-organisational-environmental (TOE) framework. Fig. 1 exhibits a research framework as the outcome of this study.

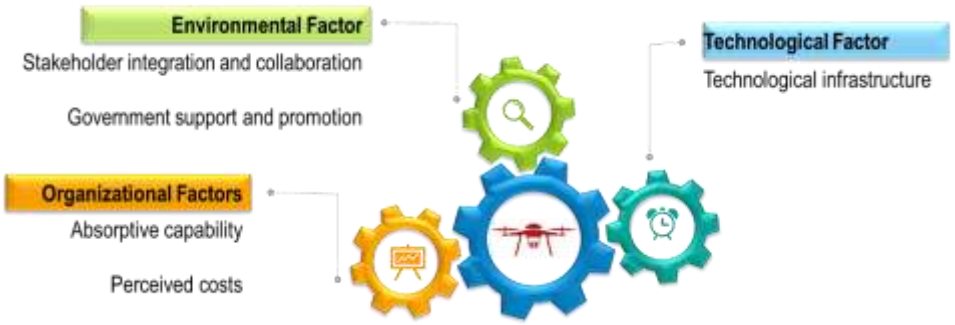

Fig. 1. Critical success factors in drone technology adoption research framework

Although this study was able to identify the key issues faced by the warehouse operator in adopting drone technology, there are still certain limitations that need to be resolved. First, more empirical data are needed for this study to perceive stronger ISSUEs on the key issues faced. Ranking the deliberated issues or identifying new and added issues will require further research. Second, the respondents are primarily warehouse professionals, which could lead to prejudice. Therefore, to yield greater ISSUEs, future research should incorporate opinions from relevant government agencies and other relevant authorities. Finally, this study solely considers the adoption of drone technology, ignoring other technologies like AI, robotics and automation, the IoT, and blockchain. To have a better understanding of the new technology adoption challenges experienced in the warehouse sector, research on different technologies is required. Moreover, future research should consider employing fuzzy Delphi and Best Worst Methods as suggested by Ali et al. (2022) to rank and select the most prominent issues encountered by Malaysia warehouse practitioners in drone technology adoption towards better drone technology strategies implementation. Despite the study's qualitative approach, its insights may help academicians and practitioners understand how drone technology is being adopted in Malaysia and provide a foundation for future research undertakings.

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Paper Contribution to Related Field of Study

This study provides future academics with easy access to data on various issues and themes related to GWP and drone technology adoption that is in line with the SDGs agenda. The authors expect this study will have a significant impact on the practitioners, particularly warehouse operators and drone developers, and how it may contribute to the SDGs.

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