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Elevating Healthcare Resilience: Role of drones in mitigating supply chain challenges in Malaysia

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Abstract
This paper explores the usage of drones in the Malaysian healthcare supply chain (HSC) and proposes strategies by identifying the challenges faced. A detailed literature review found several challenges, such as limited technical capability, strict government regulation, the need for a 5G network, and limited drone capabilities. Hence, some of the identified mitigation strategies are investment in tertiary education, government legislation improvement, expedited 5G network adoption, collaboration with NGOs, and providing drones with multi-functionality. This study contributes to the knowledge relevant to drone technology and the HSC. Future studies should investigate the practicability of drones that can support HSC management.

Keywords: Drones; Healthcare Supply Chain; COVID-19; Supply Chain Disruption; Sustainability;

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1.0 Introduction

The world is facing one of its toughest challenges in place of the COVID-19 pandemic. The global economy has been severely impacted. The current population has never experienced a pandemic of this magnitude, and recovery of the economy, for now, is uncertain. There are already existing gaps in the supply chain of raw materials and essential medications, which they were unprepared for due to destabilizing factors, pandemics included. The supply chain for healthcare has been severely affected, especially with equipment such as personal protective equipment (PPE), in which there is an imbalance in supply and demand. Governments have set lockdowns and travel bans to curb the spread of the virus (Waiho et al., 2020). As expected, this has further disrupted the healthcare supply chain (HSC). This similar occurrence has been experienced during disasters such as flooding and earthquakes, in which there is difficulty in delivering medical supplies (Govind et al., 2020).

A study from the Association for Professionals in Infection Control and Epidemiology, Inc. (APIC) discovered that in the first few months of the 2009 H1N1 influenza pandemic, there was a 2 to a 3-year backlog of supply of N95 respirators and face masks for the

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infection prevention. This is just one of the many studies proving that traditional methods are insufficient in combating natural disasters. Many technological advances have been developed to assist, including using drones in the HSC. It is important to ensure the accuracy of the material that is shared with all relevant stakeholders in the supply chain (Liu et al., 2018). The drone provides accurate information with an appropriate integration from one point to another within the supply chain (Floreano & Wood, 2015). It is not only suitable in the area of the HSC. It is capable of being applied in every area including environmental monitoring, law enforcement, military applications, and many more (Marris, 2013). With the current pandemic situation, drones are capable of performing a wide range of activities, including package delivery, inventory checking, production monitoring, simplifying administration tasks, providing real-time information, same-day delivery as well as underwater operation (Nier et al., 2020).

In the current situation, drone application in the healthcare field is relatively low for some reason. A study by Graham (2016) identified a few factors that may influence the drone application, which includes the organization, economic, political, and legislation. Additionally, relative advantage, perceived benefits, reliability, and perceived risk are other factors that may influence the drone application. In the Malaysian context, drones have been used by the police and the army during COVID-19 mainly to control public movement and conduct aerial observation to ensure the public follows the restrictions, particularly in parks and public spaces. However, the issue of cybersecurity is still in the grey area, and the government is still finding a way to ensure privacy is protected (Bernama, 2020).

Similarly, in order to control public movement, food delivery using a drone is also under trial phase to encourage the public to stay at home (Ling & Wahab, 2020). On the other hand, to improve the HSC during COVID-19, the Malaysia Ministry of Health is also looking into using drones to deliver medicines to the affected rural areas. Nevertheless, the usefulness of the exercise still needs to be determined. Thus, this study aims to explore drone applications in the HSC, their advantages, issues, challenges, and their impact on the HSC. Since drone application in the HSC is a relatively new concept in Malaysia, this study aims to propose strategies that enable it to leverage its applicability, particularly in the HSC industry.

2.0 Literature Review

2.1 Drones in the HSC Overview

Healthcare has made numerous advances over the years. Technology has always been an avenue to augment the patient experience, treatment, and management. Integrating medical devices with IT is the Internet of Medical Things (IoMT). Drones, also known as Unmanned Aerial Vehicles (UAVs), have existed for over a hundred years. The military has used these vehicles without a pilot ever since World War I (Custers, 2016). Since then, it has gained popularity in many other fields, including agriculture, commercial, logistics, and even healthcare. The use of drones is for augmenting and increasing the efficiency of healthcare.

While there are no official requirements for drones operating in healthcare settings, there are several recommendations based on generic drone technology being used in various humanitarian missions. A study by Tatham et al. (2017) highlighted that a flight endurance of 8 - 12 hours, which covers most of the daylight, could allow drones to operate with a much higher amount of time on task. Endurance is important to assist the answer in a remote and unreachable location, compared to situations where the location is nearer to the supplies. The feature of long flight hours is a high plus point in the drone industry and has always been the central focus of the manufacturer as an area to improve. Additionally, the night-flying capability would be immensely useful, especially in cases where a location might have relatively short daylight, as this would allow transporting goods to occur during dark hours, and the organization could also benefit from data maximization due to longer flights. Depending on the design of the drones, a night-flying feature would also require using infrared cameras that could, for example, help identify groups of people or individuals in an area based on their thermal signature or if there are the presence of campfires. The requirement for such endurance capacity, as mentioned in the above points, implies that the drones would need a more complex controlling system and must be able to manoeuvre beyond visual sight, and this requires the system to have a payload that can connect with satellite and advance network such as 5G for control purposes (Murray & Chu, 2015; Wahab & Khong, 2019). Like a camera with a function of infrared still and video to support the process of assessing needs whenever one arises, the extra function could also provide additional data for researchers. Thus, the ability to quickly and efficiently transmit the data generated from the camera and other sensors from the drone can be achieved. Undoubtedly, drones have been used in many countries to curb the COVID-19 spread. Some of the drones that are used for this purpose include multipurpose drones, thermal imaging drones, announcement drones, disinfectant drones, surveillance drones, and medical drones (Chamola, 2020).

India has developed its very own Corona Combat Drone (CCD), an agricultural drone remodelled for sanitation (Ulmer & Thomas, 2018). This multipurpose drone cannot only spray disinfectant but also do thermal imaging, carry COVID-19 test kits, make announcements on a speaker, and has geofencing technology (Urban Air Mobility News, 2020). On the other hand, Malaysia has used drones for crowd surveillance and to make announcements in three different languages, Malay, Chinese, and Tamil, to inform the public to stay home (Bullock, 2020). Additionally, a study on long-endurance remotely piloted aircraft systems (LE-RPAS) for humanitarian response in areas affected by disasters such as earthquakes, floods, or cyclones has been implemented under humanitarian logistics operations. There is difficulty in understanding the extent of the damage to buildings and the access routes available. This makes planning a movement for relief goods or other support extremely challenging. With the use of LE-PRAS, it will provide photographic information to the National Disaster Management Organisation (NDMO).

2.2 Drones as a Solution for HSC

There are many uses for drones in the healthcare industry. One of the contemporary applications is as a solution to the disruption of the HSC during this COVID-19 pandemic. There are many areas in which drones have proven to improve the HSC. Drone usage is very important and acts as a solution for the HSC. A study by Tucker (2017) highlighted that drones can deliver more effective healthcare services to patients while mobile or from a distance. The drone can also transport blood and other medical supplies to patients and hospitals with less hassle. Zipline and DrOTS are among the prominent companies and institutions actively researching drone usage practicability during the COVID-19 pandemic.

Rwanda is a country in Africa with challenging terrain and poor infrastructure. Zipline company, for example, has been using drones to supply blood products to over 25 hospitals and clinics across Rwanda daily. As shown in Figure 1, the technicians will store the blood in the drone's cargo bay and run through preflight prep checklists before the aircraft is launched. An electric catapult launches the drone at up to 100 kilometres per hour. These drones can make this delivery in a relatively short time. It is ideal for products with short shelf life and strict storage requirements. The drone cruises at an altitude of 120 meters and usually takes around 20 to 30 daily trips (Ackerman, 2019).

Fig. 1: Drones for blood supply in Rwanda, Africa
Source: Ackerman (2019)

From 2016-2018, Stony Brook University (New York, USA) and the Pasteur Institute of Madagascar implemented a proof of concept (POC) for bi-directional drones to transport healthcare provisions known as the Drones Observed Therapy System (DrOTS). The POC was in Malawi, Senegal, and Madagascar. The drones were able to carry sputum samples for TB and HIV, medications, blood, and injectable oxytocin for up to 120km journeys. Even though the POC used dummy samples, the POC was a success, and the respective countries are keen to adopt this technology. It was concluded that drones are worth future investments due to their compelling prospects (Knoblauch, 2019).

3.0 Research Method

The purpose of this paper is to report on a detailed assessment of the use of drone technology in the HSC and to develop effective mitigation strategies. Therefore, these research objectives are to analyze the issues and challenges of drone technology in the HSC. Data collection methods include an extensive review of past literature. The literature gathered for initial data collection comes from various sources, such as JStor, Emerald, Reaxys, Scopus ScienceDirect, Online Library, and SpringerLink Journal, which fit or are linked to keywords such as Drones, Drones Technology, Healthcare, Supply Chain Disruption, COVID-19 Disruption. The review of literature generated 29 useful works of literature from journal articles, conference papers, master thesis, books, trade magazines, and newspapers. Other resources, such as reliable news companies and blogs, were taken to include views from industry leaders. This research limits publication in the English language only and excludes other languages. All the literature was then reviewed and categorized by inclusion or exclusion of Malaysia as the country reviewed. All the information gathered was then used to develop the mitigation strategies for this study. The inclusion criteria include literature from reputable databases and sources focusing on drone technology, healthcare, supply chain disruptions, and COVID-19 impacts. Sources must be in English and relevant to the research objectives. Whereas, this study excluded non-English publications, irrelevant topics, and literature not addressing the specified keywords or focus areas.

Fig. 2: Methodology used in this study

4.0 Findings and Discussion

4.1. Challenges of Drones Adoption in the HSC

4.1.1. Vulnerability in drone operations

Exposure to hacking, such as GPS-jamming and radio control bypass, has made drones an easy target and attractive prospect for hackers. Drones can be stolen, disabled, and used to carry out cyberterrorism and other illegal activities. Recently, several government agencies have voiced concerns about drones' safety risks. The risks comprise system architecture and security vulnerability. In terms of system architecture, the 2.4Ghz radio frequency and telemetry (for further than 100m range) used in remote-controlling drones could easily be hacked and controlled by other parties, making it very dangerous if the medical supplies failed to reach the necessary location or the supplies are of controlled pharmaceutical products. On the other hand, security vulnerability concerns on the system connectivity. Some drones have Wi-Fi connectivity, which can pose a security threat to the devices and platforms connected to the network. Access points used in most drones are wired equivalent privacy (WEP) as encryption, and this technique can easily be cracked. The attacker can reach the drone's network and control devices on the other end (Custers, 2016).

4.1.2. Drones technical limitations

Drones currently have some limitations regarding battery life and loading capacity, which inhibit their ability to cover far and long distances and perform more than one delivery at a time. There is also concern about durability and justification for investment into the system. Most, if not all, non-military drones are incapable of recognizing and avoiding other airborne objects, such as other aircraft and birds (Wang & Sheu, 2019). Moreover, drone technology faces various technical challenges that impede its widespread adoption and effectiveness. Communication infrastructure poses a significant hurdle, particularly in remote or underdeveloped regions where network connectivity may be unreliable or nonexistent, hindering real-time control and monitoring of drones (Nier et al., 2020). Furthermore, adverse weather conditions such as strong winds, heavy rain, or fog can severely impair drone operation, compromising both safety and delivery efficiency. Navigation and route optimization algorithms need refinement to ensure drones can navigate complex urban environments or rural areas with accuracy and safety, especially in scenarios with unpredictable obstacles or changing landscapes. Moreover, payload capacity constraints restrict the types of goods that drones can transport, limiting their utility for certain applications like medical supply delivery or large-scale logistics. Additionally, Nelson and Gorichanaz (2019) highlighted that regulatory frameworks and airspace management systems require further development to accommodate the integration of drones into existing airspace and ensure compliance with safety standards. Overcoming these technical limitations necessitates ongoing research and innovation in areas such as battery technology, sensor capabilities, communication protocols, and autonomous navigation algorithms to unlock the full potential of drones in various domains, including healthcare, logistics, and beyond.

4.1.3. The need for 5G network technology

5G refers to the fifth generation of wireless communication technology that supports mobile networks through global connectivity. Among the benefits of 5G are low latency, high speed, increase in availability, wide range, and high reliability. Complementary technologies such as IoT and AI, which benefited from the 5G network, could change the healthcare sector and affect many other industries that are related to it. For example, the advancement in 5G technology in China has already proven beneficial in its response mechanism to the COVID-19 pandemic. The country provided better assistance to the healthcare staff and frontlines with the help of a 5G network (Osman et al., 2020). In addition to that, the 5G network has been very helpful in setting up virus tracking, patient monitoring, data collection, and analysis (Govind et al., 2020). With the use of smart wearables, drones, and mobile apps that improve the flexibility of the telemedicine market, 5G network technology is essential for realizing such functionality. 4G networks are lacking in bandwidth and speed of data transfer and, thus, cannot support high-quality, real-time long-range drone manoeuvring. However, 4G LTE networks also obstruct the attachment of the Internet of Medical Things (IoMT) devices to cloud services, rendering them unreliable (ATT Business Editorial Team, 2020). 5G, with its innovations such as ultra-low latency and high-speed data transfer, would allow mobile networks to address these issues. However, as the 5G network is still in its infancy, and most countries do not have access to the technology, practitioners can only use the existing 4G network and bear with its limitations for now (see Figure 2).

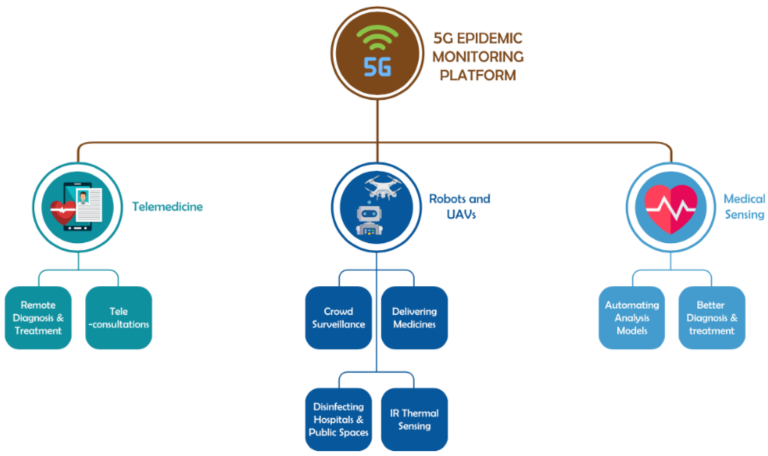

Fig. 2: 5G epidemic monitoring platform
Source: Chamola (2020)

4.1.4. Lack of reliable weather data to help flight planning

One of the external factors crucial in drones' flight planning is the weather forecast. Weather plays an important role in determining the route, height, distance, weight, and schedule of drones' operations. With reliable weather data, it is easier and safe, not to mention costly, to be operational. In bad Weather, a drone could crash and hurt people or damage things on land, get lost in flight, and effectively disrupt the supplies to vital healthcare centres (Comes et al., 2018). Accordingly, without accurate weather forecasts, drones may encounter unexpected conditions mid-flight, leading to deviations from planned routes or even forced landings. This unpredictability can result in delays, increased fuel consumption, and higher operational costs. Additionally, adverse weather conditions such as high winds, turbulence, or precipitation can significantly impact drone performance and stability, increasing the risk of accidents or damage to both the drone and its cargo (Yoo & Chankov, 2018). Moreover, without reliable weather data, operators may struggle to make informed decisions regarding the suitability of weather conditions for flight, potentially leading to missed opportunities or unnecessary risks. Addressing this challenge requires access to reliable and up-to-date weather information tailored specifically for drone operations, including forecasts for wind speed and direction, temperature, humidity, and precipitation. Integration of weather monitoring systems and real-time data feeds into drone management platforms can enhance situational awareness and enable proactive decision-making to mitigate risks associated with adverse weather conditions. Additionally, advances in weather prediction algorithms and sensor technologies can further improve the accuracy and timeliness of weather forecasts, ultimately enhancing the safety, efficiency, and reliability of drone operations in various industries (Benarbia & Kyamakya, 2022).

4.1.5. Government regulation

In many countries, incorporating drones into the COVID-19 impact response system is bounded by the inconsistency of government regulatory policies (Chamola, 2020). As the pandemic shocked the world, many things are affected, and the government needs to prioritize life-affecting regulations before anything else. Thus, it is understandable that the drone regulations have not been updated since COVID-19. However, certain policies needed to be clarified even before the pandemic started. For example, the US Federal Aviation Administration (FAA) requires commercial drones to go through the same safety and economic reviews, known as Part 135, as a 12-passenger private jet. Not only are both vehicles in a different class, but some of the requirements are also irrelevant to drones. Figure 3 details the differences between private jets and drones. In Malaysia, the Civil Aviation Authority of Malaysia (CAAM) is the national aviation authority responsible for managing aircraft-related matters. There are a few essential rules to follow in order to fly a drone in Malaysia. One of the rules is the limitation on drone flights to daylight hours and requirements for commercial users to keep their aircraft within their visual sight (Osman et al., 2020). The limitation will hinder most drones' flight for supplies of healthcare products as the drop-off locations would be further than the visual distance.

Fig. 3: FAA requirements for commercial planes vs. drones

Source: Descant (2020)

4.1.6 Beyond Visible Line of Sight (BVLOS)

Although considerable advances in drone technology have recently been made, drone operations Beyond Visible Line of Sight (BVLOS) remain unsafe. While it is a known regulation, more importantly, it is why it is being ruled as such. Evidence showing BVLOS is as safe as manoeuvring drones within sight is still lacking. Operational guidelines and technical assistance are increasingly needed to guarantee the security and safety of the operation of drones. From a practical perspective, most drones, especially non-commercial ones, are designed to be operated on a visual sightline basis (Marris, 2013). The controller must always have direct visuals of the drones and the surrounding area, including the terrain and treelines it operates. This would mean there is a limit of a 1.5 km radius between the operator and the drones. However, the actual field of operating flight area can be extended by following the drones using a car or a boat while maintaining the rule of a maximum 1.5 km distance. However, some companies and organizations are lobbying the authorities for approval to undertake beyond the visual line of sight where the drone pilot can rely on one or more remote observers to keep the unmanned aircraft always in sight. These observers then transmit flight information to the controller via radio, helping maintain a safe separation from other aircraft.

4.1.7 Limited technical capability

From a supply chain management perspective, the drone's reliability depends on the availability of trained personnel who operate and maintain the drone and its system. From a more strategic perspective, to handle the drones efficiently and apply a lean management strategy to the system, warehouses and distribution centres need to match supplies as customers demand. Given the current push-based approach to PPE campaigns with long lead times, this requires a shift in the supply chain strategy to ensure that local requirements can be met in real time. Otherwise, this strategy will only lead to an inefficient distribution of inventories and, ultimately, defeat the purpose of drones' usage in managing the supply chain during a pandemic (Comes, 2018). Another critical aspect affecting drone encompassing aspects beyond personnel training and maintenance. Technical challenges such as battery life, payload capacity, and navigational accuracy significantly impact drone performance. Additionally, interoperability with existing supply chain systems and integration with inventory management software pose hurdles (Nelson & Gorichanaz, 2019). Overcoming these limitations requires investment in research and development to enhance drone technology and streamline compatibility with supply chain infrastructure, ensuring seamless operation and effective utilization in pandemic response efforts.

4.1.8 Adaptability

Introducing new logistic methods like drones will require certain degrees of adaptability by the whole supply chain. A new system and requirements, either manual or automatic, need to be created in order to adopt drones into the supply chain. Drones must consider limitations such as weight per trip, temperature control, and new systems. There is also a concern for a new learning curve for existing workers in the supply chain, which will be a challenge, especially during a critical time when systems are required to run efficiently. The indicators for the HSC that use drones as their logistics mode are like conventional logistic vehicles. However, the measurements are slightly different. Some indicators of the healthcare system's performance include health facilities, patients reached, and health outcomes. Meanwhile, the indicators for supply chain management induce turn-around times, no samples, stock-outs, commodity or sample types, quantity, weight, volume/size, quality, no successful deliveries made, and payload damage or loss (Ulmer & Thomas, 2018). In addition to creating new systems and requirements, adaptability within the supply chain also necessitates a shift in mindset and organizational culture. Embracing drones as a logistics method requires not only technical adjustments but also changes in workflows and decision-making processes. This adaptability entails fostering a culture of innovation and continuous improvement, where stakeholders are willing to experiment with new technologies and methodologies (Benarbia & Kyamakya, 2022). Moreover, effective communication and collaboration among different stakeholders are essential to ensure seamless integration of drones into the supply chain and mitigate potential disruptions. Building this adaptability capacity within the supply chain enables smoother transitions and enhances overall resilience in responding to dynamic challenges, such as those encountered during pandemics (Nier et al., 2020).

4.1.9 Cost

Mailey (2013) noted that there is no standardized way of generating "cost/flight hour" or a similar metric. Nevertheless, Figure 5 shows drones' technical specifications and costs to give a better perspective on the feasibility of adopting a drone system. The financial benefits of utilizing drones to serve HSC needs can only be seen when the system runs at maximum capacity and the marginal cost of each flight is reduced to a minimum. In order to reduce costs and increase efficiency, companies could outsource a drone service provider, or a group of agencies within a regional interagency network could share the cost to develop their system and use it alternately. A collaboration would help minimize risk and help ensure a shared return for all the parties involved in their investments (Tatham et al., 2017). Aside from technical specifications and flight costs, other financial considerations include initial investment, maintenance expenses, and regulatory compliance costs. Additionally, factors such as insurance premiums and potential liabilities should be factored into the overall cost analysis. Companies must carefully evaluate the total cost of ownership and weigh it against the anticipated benefits to determine the feasibility and ROI of adopting a drone system in healthcare supply chain operations (Nier et al., 2020).

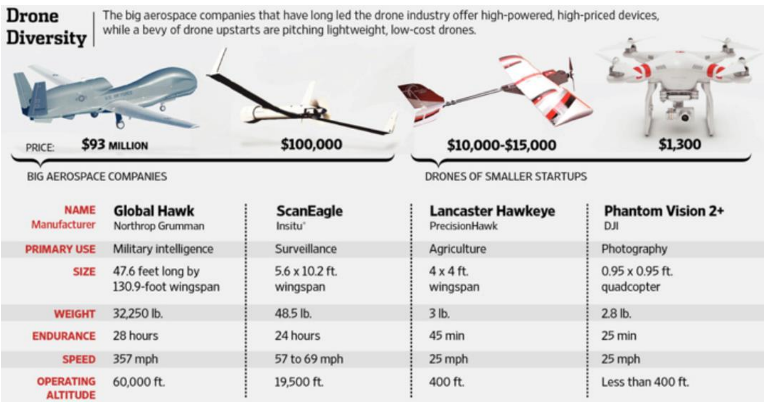

Fig. 5: Drones technical specification and its cost
Source: Mailey (2013)

Challenges faced in onboarding drones as part of the HSC would be crucial to address as the domino effect could further disrupt the whole chain, especially the end-users. Some of the prominent challenges include supplier disruption. Having supply disruption would be counter-productive in adopting drones for HSC. Supplies could be interrupted due to poor supply flow, inefficient route planning, weather-caused rescheduling, drone breakdown, and bottlenecks from untrained personnel in adopting the new system (Liu et al., 2018). Furthermore, the patient backlog is another challenge faced by the industry. The end-users, like hospitals and clinics, would need less adoption of change with the use of drones in the HSC but will be majorly affected if things do not go as planned. Medical personnel cannot perform efficiently if there is a bottleneck in the supply chain. Ineffective usage of drones to send specimens such as COVID-19 throat swabs to the central laboratory could cause late diagnosis and eventually cause a higher spread of the disease where it should be contained (Knoblauch et al., 2019). In addition to the unavailability of drones to assist in supporting the delivery of healthcare supplies, logistic workers are required to have a higher frequency of close contact with high-risk groups like healthcare workers which might expose logistic workers to greater risk (Graham, 2016). Undoubtedly, the inefficiency of the supply chain can only be achieved with a drone application. The route planning, inventory, and order would need more real-time collaborations. While this allows for better efficiency, it could also cause more delays if even a part of the system needs to adapt and onboard effectively. Wastage regarding higher waiting time, over or under orders, and extra processing could reflect drones' adoption as a fancy gimmick (Nier et al., 2020; Giones & Brem, 2017). However, the cost is always the main issue for the organization to adopt drone technology. Including drones as part of the HSC will already cost a lot of money. Without effective and efficient adoption, there will be a higher monetary cost and related costs such as higher mortality and morbidity of patients (Rajendran et al., 2018). As highlighted by Tariq (2019), it is time for Malaysia to update the drone laws and provide more training to ensure the personnel know drone management.

5.0 Conclusion and Recommendation

5.1. Conclusion

While the world is experiencing sudden and devastating changes from the COVID-19 pandemic, the emergence of various technologies, such as drones and 5G, are facilitating the impact mitigation effort. This study offered some of the latest insights into the COVID-19 pandemic and how drones can help minimize disruptions in the HSC. This paper started with a general review of drones and their recent application in the healthcare and health supply chain. In order to relate to the impact of COVID-19, this study also dived into the functionality of drones in the previous pandemic crisis and the implementation challenges. This study identified drone technology interventions in the direction of COVID-19 impact management in the HSC. From the intensive literature review and field observation, the 5G network shall equip drones to offer higher versatility in functions and bigger areas of services. Regulations on drones are also encouraged to be revised based on the latest developments in the industry. To ensure enough manpower in drone operation, education institutions should strive to get certification accreditation. While it is noted that a few challenges are limiting the rapid adoption of drone technology, its immense potential in supporting the HSC cannot be overlooked. Government bodies and authorities should lead the collection and data assessment in local drone projects and invest more in drone research and development as the trend and adoption of this vehicle into the healthcare industry will only go one way up.

Being among a few studies to investigate drone technology application in the Malaysian HSC, a limitation of this study is the extremely subjective findings, relying heavily on the author's literature search and observations. Findings may lack generalizability and robustness, emphasizing the need for quantitative research for substantiated outcomes. Additionally, as the HSC industry evolves, proposed mitigation strategies may require adjustments. Future studies should employ empirical methods and engage with focus groups to gather more diverse and valuable insights, particularly concerning drone technology applications in healthcare, in Malaysia and beyond. The emphasized issues, challenges, and mitigation strategies are based on the author's literature search and current drone practice observation in the healthcare industry. Hence, future research should go through quantitative research to make the outcomes more substantiated and significant. Furthermore, as the HSC industry continuously advances, the proposition from this study, particularly on the mitigation strategies, should be treated as a guideline, considering it may change in the future. Thus, future research should focus more on empirical and structured studies. Future studies are also suggested to engage with the focus groups to achieve more valuable insights towards the overall drone technology application in the healthcare industry, particularly in Malaysia and other countries.

5.2. Recommendations

Certain aspects of the Malaysian HSC could benefit from the adoption of drones. Certain rural areas exist, especially in places with no good access roads. This study found that drones could complement the supply chain of these areas in tackling COVID-19 more efficiently. Firstly, a nationwide 5G network would be an ideal environment for the movement of drones around the country. According to Malaysia's former Prime Minister, the country will launch 5G technology commercially by the third quarter of 2020. If Malaysia can fast-track that technology, it would greatly benefit the healthcare sector. For instance, Telekom Malaysia is developing Langkawi Island as Malaysia's first 5G standalone network. The pilot project or proof of concept for our drone technology could be used in Langkawi Island to interlink the Langkawi Hospital and its surrounding clinics. Pilot projects are ideal in a smaller region or sample size as problems will be anticipated, and they can be rectified before nationwide implementation.

Furthermore, improving the legislation for drones operating in healthcare services is important. Two policies that have heavily affected the drones' operations, particularly in healthcare services are daylight hours flight and beyond visible line of sight (VLOS). Currently, drones are only allowed to fly during daylight with visible sight, where medical supports are not bounded by time or location, and services are always required to be operational. Most importantly, to reach beyond visible sight (~1.5km). While it is understood that this legislation is implemented for safety reasons, more research should be done to ensure that unempirical reasons do not bind the limitations. The potential for drone adoption in the HSC is huge, especially in disrupted conventional HSC events like COVID-19.

Meanwhile, the government should expedite the accreditation of certifications offered by educational institutions for commercial drone operations. While there are a few academics and institutions like Drone Academy Asia, Aviation Management College, Asia Drone and IoT Technology that offer programs like Certified Drone Operation Proficient, Certified Drone Aerial Mapping And Surveying Proficient, Certified Drone Inspection Proficient, Certified Drone Maintenance And Repair Proficient, none of the courses are accredited by Malaysian Qualification Agency (MQA) while at the same time, are being accredited by international bodies. Accreditation is the rank or recognition of an MQA standard assessment. It also offers a framework for certain actors to accept the system for several reasons. For example, the Public Service Department (PSD) will use this accreditation status to recognize qualifications for public service employment. Academic bodies can use the accreditation of accredited graduates for registration as academic engineers.

On the other hand, the cost could be one of the biggest reasons that hinder organizations from considering drones in their supply chain lineup. Thus, collaboration with NGOs and businesses to share the cost of drone usage in the HSC is essential. Other than the new learning curve and creation of new SOPs and regulations in their existing system, the cost would only add up to more hesitations. Drones are likely to change the landscape of the supply chain, including in the healthcare sector, and investments made today will pay off in the future when the system stabilizes and cost/benefit reduces as supplies slide from conventional ways to drones. Small and medium organizations should start collaborating and sharing the cost of implementation as part of their value supply chain. Operating drones involves multiple aspects, such as pilots, maintenance, insurance, system development, and others, not to mention the cost of owning the drones. By sharing the cost or creative collaboration, more organizations can benefit from integrating drones into their supply chain ecosystem.

There needs to be more PPE supply due to the increased usage and requirement in hospitals and clinics. There have been donations of PPE from NGOs that are being consolidated by organizations such as myPPEhub. Currently, the donated PPE is being manually transported to hospitals or clinics that are in dire need. A collaboration with myPPEhub in distributing PPE would make the supply more efficient. Drones could be deployed immediately after a PPE is collected and transported to facilities within a 100km radius. According to the World Health Organization (WHO), there are very strict guidelines on the collection, storage, packaging, and transport of COVID-19 swab specimens. These guidelines are in place to protect the specimens and the staff handling them. Specimens that can be delivered promptly to the laboratory can be stored and shipped at 2-8°C. When there is a tendency for the specimens to be delayed in reaching the laboratory, using the viral transport medium is strongly recommended. At the same time, specimens may be frozen at -20°C or, ideally -70°C and shipped on dry ice if more time is required to reach the laboratory (WHO, 2020). Drones would be a much safer option in transporting specimens to laboratories. This could be proposed to the Ministry of Health or private clinics with a large sample size.

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