Aerial Platform Reliability for Flood Monitoring Under Various Weather Conditions: A Review

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Abstract Flood is an annual disaster in Malaysia, especially in the east coast region. Recently, other regions in Malaysia have experienced devastating flood as well. To monitor the flood extent, aerial monitoring approach is considered as one of the best measures. Compared to space borne remote sensing, aerial platforms are more reliable in obtaining real time data with higher spatial resolution. Among the obstacles in using space borne remote sensing approach are cloud coverage and revisit limitations, making it less desirable option for flood monitoring. In this chapter, a review of four types of aerial platforms that perform remote sensing task is presented, namely; rotary wings, fixed wings, blimps and helikites. The main criteria discussed in the review are payload capacity, endurance (flight duration), altitudes, tolerable wind speed, vertical take-off and landing ability, and the ability to perform under adverse weather, such as heavy precipitation and winds. From the findings, there are lack of studies that mentioned about the capability of aerial platform in rough weather conditions. Out of all four types of aerial platforms discussed, helikite is seen to be the most suitable device to fly in adverse weather. Nevertheless, the only drawback in using helikite is that it has mobility issue since it is tethered to the ground. Helikite application is suitable for small area coverage. As for future recommendations, the study to evaluate the helikite's reliability in performing such task has a great opportunity to be pursued further.

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1 Introduction

Natural disasters bring atrocious effect to the people around the world. In some cases, the physical extent of the disaster may escalate and become complex, causing sudden disruptions which makes it impossible for the affected community to react and respond accordingly. Efforts have been made by various parties to manage disasters in terms of response, damage assessments, and recovery after the disasters end. Recent studies shown that natural disasters, especially flood, will be more frequent because of the climate change effect (Erdelj et al. 2017). Compared to other natural hazard, flood is one of the most destructive natural disasters, which causes severe damages and kills more lives each year (Smith et al. 2014). As one of the measures to identify possible flood event and planning for actions, flood maps are put into use. Flood map, often referred to as flood risk or hazard map, is presented in graphical format that marks the areas with flood history, have potential of being flooded, or considered to be at risk of flooding. Among the features displayed by the maps are information such as flows, water levels, depths, and others. By utilizing flood maps, planning authorities assess useful information, such as to monitor flood direction as well as making flood damage assessment (Auynirundronkool et al. 2012).

As at current, flood mapping is considered important in organizing and coordinating emergency services' response during flood (Giustarini et al. 2015). To date, satellite remote sensing is considered as one of the best tools to acquire flood map information. In many countries, authorities have opted using airborne and satellite imagery to assist plans in the event of floods. However, several factors can cause difficulties to the system, such as shadow and layover effects, as well as cloud covers which complicate the detection of flood water pixels (Tanguy et al. 2017). Regrettably, satellite images are not consistently obtainable in real time. To solve this issue, in situ surveys are favoured in some occasions. Recent technologies in innovations such as unmanned aircraft system (UAS) or unmanned aerial vehicle (UAV) allows us to capture image and assessing the flood extent. Its characteristics such as flexibility, safe, easy to operate, and relatively low cost allow the unmanned aerial platforms to be utilized in disaster events (Xu et al. 2014). Unfortunately, most of small aerial platforms are inappropriate to lift heavy load in massive areas in a short time period. Furthermore, operational distance is only limited to the radio link range within 5 km with the ground control station as mentioned by Gonçalves and Henriques (2015).

Apart from that, studies by Díaz-Vilariño et al. (2016) also highlighted several criteria of limitations in its operational task namely; the altitude, endurance, range of controls, payload capacity, manoeuvrability, tolerable wind speed, and conditions of weather. To date, assessment of the image quality extracted from a non-metric camera mounted on aerial platform board in adverse weather was not one of the considerations (Kedzierski and Wierzbicki 2015). It is important to note that in aerial missions, there are possibilities that the weather and criteria limitations of aerial platforms may affect the data collection's reliability. Thus, the aim of this study is to review existing unmanned aerial platforms, namely four major types; rotary wing, fixed wing, blimps, and helikite. This review puts consideration in the criteria of limitations and the operability of the platform under different weather conditions during disaster event, especially for flood monitoring.

2 Overview of Flood Monitoring

2.1 Flood in Malaysia

Flood is rather common and considered as the most significant natural hazard in Malaysia in terms of damage it does, occurrence frequency, area affected, flood duration as well as social economic impact (Roosli and Collins 2016). Malaysia has 189 river basins throughout the country, including in Sabah and Sarawak. In Malaysia, studies have shown that at least 3.5 million from its population reside on flood plains which expose them to flood probabilities (Mustaffa et al. 2014). Several factors are identified to be the potential cause of seasonal floods in Malaysia which among others are; increased number of development, changes in water collection and flows, substandard drainage system and most importantly the natural factors such as heavy monsoon rainfall, intense convection rain storms and other local factors (Mohd et al. 2016).

Among the country's worst case of flood history occurred in December 2014, in which a severe flood hit multiple states in the east coast of Malaysia such as Pahang, Terengganu, and Kelantan (Othman et al. 2016). About 3,390 people in Kelantan and 4,209 in Terengganu were temporarily evacuated. Prolonged rain had cause water level rose at most of the rivers beyond safety levees, forcing thousands people to be evacuated on the following day. The aftermath of flooding damages estimated reached up to 1 billion ringgits ($284 million USD). The last time the region experienced disastrous flood was in 2000 where 15 people killed and more than 10,000 people fled their homes (Ruiz Estrada et al. 2017). The affected victims were evacuated from their homes to designated temporary shelter facilities situated on higher grounds in each areas respectively (Aishah et al. 2015). A study by Abu Talib et al. (2018) mentioned that flood occurrence in Malaysia impacted the housing, health, education, and cultural heritage. The incident in Kelantan, for example caused physical destruction with total 14 casualties and temporal displacement of 158,476 victims.

Recent Malaysian Eleventh Plan (2016–2020) has stated three strategies under the sixth chapter; pursuing green growth for sustainability and resilience. The first strategy is by strengthening disaster risk management (DRM), by establishing DRM policy and institutional framework, improving disaster detection and response capacity, incorporating DRM into development plans and creating community awareness. Secondly, improving flood mitigation by generating new investments from flood mitigation projects, enhancing long-term planning and strengthening flood forecasting and warning systems. Thirdly, enhancing climate change adaptation by developing a national adaptation plan, and strengthening resilience of infrastructure, natural buffers including water and agriculture (Rancangan Malaysia Kesebelas 2015).

The plan also emphasises on strengthening risk management during natural disaster through five phases; prevention, mitigation, preparedness, response and recovery. Other than that, numerous actions including regulations amendments, construct early warning and alert systems for disaster, mitigation structures, awareness campaigns, establish funds for national disaster relief, amend standard operating procedures, as well as collaboration with international organizations have been taken to upgrade emergency preparedness during natural disasters. Even though the Malaysian government already has procedures in place to handle flood disasters, there are still more opportunities to achieve better flood disaster management (Mohammed et al. 2018). Having mentioned that, this allows room of opportunities for research in the area of unmanned aerial platforms' application in disaster management.

2.2 Flood Monitoring and Mapping

In general, flood is caused by intense precipitation, and also known as the predominant cause of disruption in various sector, especially in transportation (Pregnolato et al. 2017). Currently, during the event of flood, the road assessment is made through assumptions of whether the road is either operational or blocked, without being backed up by real time observations. This method causes unnecessary disruptions and delay in resources management during flood. Based on the issue stated above, it is crucial to utilize a real-time flood extent map in managing and monitoring a disaster scenario. With the purpose of aiding the community in emergency planning, flood extent and hazard mapping is currently being developed and put into use, although it is still considered at an early stage (Zhang et al. 2015).

Near-real-time flood maps are essential to organize and synchronize emergency services' response actions during the events of flood (Shen et al. 2015). Chen et al. (2013) highlighted the issues and approaches in disaster management on the applications of UAV systems which are classified in different application domains within three main groups, namely; monitoring, response and forecast. Due to various reasons, current practises in disaster management programmes deploy resources and help from outside of the disaster zone. Unfortunately, this practise is prone to produce delay in disaster management as well as recovery efforts, which may cause a consequent loss of human lives and unnecessary waste of economic resources. Hence, it is deem important to note that mapping out disaster tendency and the availability of resources in advance is crucial to expedite damage recovery and at the same time prevent casualties (Mishra et al. 2012).

In common practise, flood mitigation approaches and planning are conducted based on the assessment of the flood occurrences in terms of location, magnitude and distribution. Xiao et al. (2017) mentioned that flood hazard and risk analysis are mainly carried out with hydraulic model that simulate flood inundation extent, water depth and velocity. However, these modelling were often carried out from either space borne or satellite remote sensing data in testing condition, which means the data retrieved from the study was not real time and on certain circumstances, the data was affected by cloud covers.

Additionally, to gain a better accuracy output, flood modelling and flood monitoring should be carried out simultaneously (Tuna et al. 2012). This is due to the fact that flood modelling requires numerous amount of data and flood inventories such as extensive historical rainfall data, water level data, discharges and return period data, and others (Rollason et al. 2018). In most cases, insufficient amount of previous data (discharge and water level) becomes the prime barriers in predicting the water surface profile for water catchments. Apart from that, limited amount and the unmanaged conditions of some gauging stations along the river also contribute to the insufficient data collection of flood modelling (Mohammed et al. 2011). Hence, it is explicit to note that in order to achieve an ideal flood modelling, it requires integration of real time monitoring to gain accurate and reliable results.

It is a known fact that flood modelling approach may simulate and generate the flood extent map. To obtain more reliable and accurate results, the collected data must be combined with real time monitoring of flood. The quantification of dynamic and previously immeasurable hydraulic phenomena is now made possible through aerial image acquisition of flood occurrences. However, the possibility of this approach to provide dependable information on the hydraulic conditions during dynamic and high-energy flash floods has yet to be explored (Perks et al. 2016). In reality, it is insufficient to monitor flood events by relying solely on conventional rainfall stations and river water level stations because flood develop at space and time scales that conventional measurement methods by using samples of precipitation and river discharges are unable to be conducted effectively (Zoccatelli et al. 2010).

In view of that problem, hence, it is significant to have a more creative solution in flood monitoring such as aerial monitoring in order to obtain the flood extent map with time-step intervals, predict damages, and improve decision-making by emergency responders. To obtain aerial monitoring, aerial platform or UAVs can be utilized to carry small sensors for data acquisitions, which raises question of which aerial platforms are the most suitable for a real time flood monitoring under different weather conditions.

2.3 Unmanned Aerial Platforms

UAV or UAS is an unmanned aerial platform in the form of an aircraft that operates without a human pilot on board. The vehicle is controlled either autonomously or by an operator on the ground which enables it to be used to conduct aerial missions (Liu et al. 2014). Research by Visser et al. (2013) indicated that the UAV were initially designed to regulate military communication for tasks such as spying and message deliveries. However, over the years, the UAV application has been gradually shifted to common usage such as to conduct researches as well as applications by civilians. Among popular applications of UAV are in the area of mapping, monitoring environmental changes, disaster response, exploration of resources, and others (Ludeno et al. 2018). UAV applications are rather favoured by many, compared to other flying vehicles and satellite remote sensing technology as they have two advantages to capture aerial photographs, namely; low cost and high mobility (Xiongkui et al. 2017).

In spite of that, UAV applications also have a number of environmental restrictions on their usage due to low flight stability especially under extreme weather conditions (Paneque-Gálvez et al. 2014). Analysing data collected through UAS or UAV can be meticulously conducted by professionals while at the same time reducing operational costs and safety, when paired with visual and audio recording, photography, or multi spectral imaging. The usage of UAS or UAV is also well known for its benefit in safety, economy and operational efficiency to carry out various kinds of surveying as well as monitoring applications (Rakha and Gorodetsky 2018).

Specifically, the unmanned aerial platforms are important because they have the capability to generate the information promptly whereby the data can be immediately conveyed to the coordination team, highlight the local assessment, effectively detect blocked areas as well as identification of secondary disasters, in which all the aforementioned benefits may help in increasing logistic efficiency during the disaster (Silva et al. 2017). In order to facilitate the need of the UAV in flood events, small sized UAVs are found to be more reliable in providing the researchers different views of the situation and also much easier method for remote sensing, especially if it is to be used in monitoring (Chao et al. 2010).

Additionally, the usage of UAV consumes less time than other techniques for data collection and therefore reduce the total costs (Martínez-carricondo et al. 2018). Apart from that, UAV imagery produces better results in terms of resolution and accuracy compared to satellite-derived products. Also, UAVs are found to be useful in situations where the use of other techniques to acquire data is unsafe (Agüera-vega et al. 2018).

It is also important to note that accurate imagery of the environment is essential to applications such as topographic modelling, mapping, environmental monitoring, and others. Recent advances in hardware and software technology development allows for more accurate results. The advantages of the new technology developments are utilization of low-cost digital cameras and navigation systems, but at the same time providing high scale, time efficient and low cost facility in aerial surveying, mapping and monitoring (Ajayi et al. 2018).

3 Aerial Platform Reviews

3.1 Rotary Wings

Rotary wings have a number of rotors installed on its body. For instance, a single rotor helicopter is a model with one rotor on top and one on its tail, while quad copter, hexacopter, octocopters are multi-rotors that are propelled by four, six, and eight rotors respectively (Mogili and Deepak 2018). Rotary wings are known for vertical take-off and landing (VTOL) capability, hovering and low speed manoeuvre. Since, they do not require a runway or any heavy facilities, the rotary wings are more preferred compared to fixed wings (Basset et al. 2014).

Furthermore, a rotary wing is capable of flying in windy conditions up to 50 kmh^{-1}. Not only it can perform static flights, which is appropriate to be used in monitoring process due to the hovering ability (Nonami et al. 2010), but it can also mount various camera instruments for aerial monitoring task (Delacourt et al. 2009). Over the years, different types of rotary wing UAV have been developed for photogrammetric data acquisition and topographic modelling (Coppa et al. 2009).

Most of the times, rotary wing UAVs can demonstrate slower cruising speed and relatively shorter flight durations (up to 50 min). The capability to hover at one fixed position enable them to hold a steady field of view for extensive time frame. Many organizations view the rotary wings as recommended device for monitoring because of their capability to circumnavigate in various angles without the necessity for a runaway in taking off and landing protocols (Brouwer et al. 2014). However, duration of rotary wings flight depends critically on both battery and payload weight. According to Uysal et al. (2015), the heavier the payload, the quicker the battery drains out. Apart from that, weather conditions such as strong winds also affect the endurance of the flights, which also cause the flight time to be shorten.

Daakir et al. (2017) presented a system consisting of a single-frequency GPS receiver coupled with a light photogrammetric quality camera embedded in a rotary wing UAV, which aimed to obtain high quality data for metrology applications. The sensors used are specifically designed to be used for close-range aerial image acquisition. Lever-arm calibration and time synchronization are performed on timely basis to maintain accuracy. The study also showed that an accuracy of a few centimetres could be reached by using the system which combined the usage of low-cost UAV and GPS module coupled with the home-made camera.

Connor et al. (2018) conducted work on aerial photogrammetry obtained using a rotary wing UAV which flew at low altitudes, merged with ground-based radiation mapping data acquired at an interim storage facility for wastes removal as part of the large-scale Fukushima clean-up program. The investigation was aimed to assess the extent of the remediation program at a specific site that still has the radiation contaminants. Based on the result, the researchers discover a powerful graphic confirming the elevated radiological intensity exists at the site containing the waste bags. The whole survey consumed less than one hour, and was subsequently post-processed using graphical information software to obtain the renderings. The

Table 1 Examples of rotary wing UAV

Model	Fazer R G2	DJI Inspire 2	DJI Matrice 200	DJI Matrice 600
No. of motors	1 (Single)	4 (Quad)	4 (Quad)	6 (Hexa)
Wingspan	3.15 m	0.63 m	0.887 m	1.668 m
Overall length	3.66 m	0.63 m	0.880 m	1.518 m
Cruise speed	70–80 kmh^{-1}	70–80 kmh^{-1}	70–80 kmh^{-1}	50–60 kmh^{-1}
Endurance	60 min (fuel)	27 min (battery)	24 min (battery)	18 min (battery)
Maximum altitude	2,800 m	4,500 m	3,000 m	2,500 m
Payload	35.0 kg	0.7 kg	1.6 kg	5.0 kg
Wind tolerable	20 ms^{-1}	10 ms^{-1}	12 ms^{-1}	8 ms^{-1}
Launch	Vertical	Vertical	Vertical	Vertical
Landing	Vertical	Vertical	Vertical	Vertical
Range of flight	30,000 m	7,000 m	7,000 m	5,000 m
Cost	$120,450	$2,999	$9,000	$5,500

conclusions of their study also deduced that the present monitoring methods of the storage facilities could be upgraded through the integration of UAVs within the existing standard protocol.

In general, integrated monitoring approach is proven to be able to provide a spatially detailed assessment by combining high resolution UAV remote sensing with rotary wing technology based on its ability to hover and agile manoeuvre (Filippo et al. 2017). Some examples of rotary wing UAVs are shown in Table 1.

3.2 *Fixed Wings*

Fixed wing UAV is very similar to a miniature airplane. This type of UAV has been known for its capability to fly for long durations and able to accelerate the speed up to 80 kmh^{-1}. With the combination of high speed and long endurance, fixed wing is a definite choice for photogrammetric mapping task in larger areas at high spatial resolution (Brouwer et al. 2014). According to previous studies, fixed wing UAVs have flown over cities and wetlands in order to assess damage level after natural disasters like earthquakes, hurricanes, and floods. As an example, a predator drone successfully produced infrared imagery which then allowed officials and relevant authorities to execute reasonable decisions in a disaster event as highlighted by Conniff and McClaran (2011).

High-resolution fixed wing UAV imagery was proposed by Feng et al. (2015) for urban flood mapping as the fixed wing works as an excellent platform for urban flood mapping which ensures accurate extraction results in dense urban landscapes during flood event. Technically, UAVs operate with the concept that their fixed wings use forward airspeed for lift generation. In cases of long flights duration, fixed wing is highly preferred as it is more energy efficient, but on the other hand, it is also important to note that this concept does not permit hovering in the air (Gabrlik 2015).

Nowadays, fixed wings are commonly used for mapping, search, and rescue applications which need accurate tracking of inertial trajectories capabilities. Nevertheless, fixed wing platforms are sensitive to wind conditions that are prone to influence the vehicle inertial track. Based on this, it is possible that the trajectory tracking capability of the platform to be jeopardized, in cases where the embedded control system is not appointed as a wind disturbances (Brezoescu et al. 2015). Furthermore, unlike rotary wings, fixed wings require landing strips and trained pilots to operate the platform which necessitate the consideration of a spacious runaways.

According to Fan et al. (2017), even with autonomous flight features, it is still obligatory for fixed wings to have experts in landing and take-off since fixed wings are incapable to perform the vertical take-off and landing (VTOL). To date, the advantages of fixed wing platforms are only high lift-to-drag ratio, fuel-efficient flying, and high-speed flying, which make them a reasonable choice in aerial mapping. The obligations of having long runway and trained pilots to conduct take-off and landing, however, have turned the fixed wings as less recommendable option compared to rotary wings (Hong et al. 2013).

A study by Turner et al. (2016) have used a coastal engineering application of fixed wing UAV to represent the practical use and potential benefits of the surveying technology. In the span of two years of research, rapid post-storm deployment of UAV surveying was successfully integrated into an established four decades coastal monitoring program at Narrabeen Beach, Australia. Due to this, the scope of their research was extended to include detailed measurements of dune and beach surface erosion along the 3.5 km embayment at a spatial scale and temporal resolution that were unfeasible during previous research.

The survey data collected in that study were obtained using a fixed-wing, off-the-shelf, RTK-GPS UAV (SenseFly eBee-RTK) that was initially manufactured commercially for the professional survey purpose. The feature of the fixed wing was indeed applicable for the purpose of surveying with a wingspan of precisely below 1 m, weightage of 700 g, approximately 40 min flight-time per battery that enables coverage area of 2 km^2 during low wind conditions, or lesser areas in stronger wind condition of 45 kmh^{-1}. At present, the survey-grade UAV equipment are readily available off-the-shelf, complete with data processing and analysis tools for practicing coastal engineers, managers and researchers.

Apart from the regulatory constraints that determine their use, UAVs bring forth efficient and cost-effective survey tool for topographic mapping as well as measurement in the coastal zone. It is also sufficient to mention that the availability of off-the-shelf UAV survey systems combined with high-precision RTK-GPS positioning decreases the demand for any supplementary ground surveying equipment.

Other study by Iersel et al. (2018) aimed to assess multi-temporal high spatial-resolution imagery performance of the recorded dynamics in floodplain vegetation height and greenness which was collected with a UAV. In the study, field reference data on vegetation height were collected six times in a year at 28 field plots situated at a single flood plain along the Waal River, the main distributary of the Rhine River, Netherlands. The results proved high potential of using UAV-borne sensors in order to increase the classification accuracy of low floodplain vegetation along the area of the framework of floodplain mapping.

Fixed wing UAV has provided the community with a flexible, variety remote sensing tool with a wide range of payloads and applications. Of late, fixed wing UAV systems carry RGB, colour infrared, thermal infrared, spectrometers as well as LiDAR systems. Impressively, technical developments are changing rapidly which contribute to more diverse and wider coverage of UAV applications due to its cruising ability (Hemmelder et al. 2018). Table 2 shows some examples of other types of fixed wing UAV.

3.3 Blimps

Blimps or dirigibles are a form of light air vehicles which started as hot air balloons which later evolved to using lifting gas, tethered and un-tethered aerostats, airships, and novel buoyancy air vehicles in step with the advancement of new materials and technologies. Among the main advantage of blimps is that it is low in cost and energy consumption. Blimps have the capability to hover for a long period of time which cause their refuelling and operating costs to be much lower compared to conventional fixed-wing or rotary wings (Liao and Pasternak 2009).

In earlier days, low-level aerial photography was acquired using various kinds of unmanned platforms including small blimps (Tonkin et al. 2014). A blimp's lift generation mechanism uses light lifting gas which makes it different from other aerial platforms. Unfortunately, due to its frail structure and aerodynamic features, a blimp is incapable of withstanding strong winds during high wind condition, compared to other unmanned aerial platforms (Li et al. 2011).

Table 2 Examples of fixed wing UAV

Model	F-3	AIbird KC3000	F-5	Chilong
Wingspan	1.7 m	3.1 m	4.6 m	3.1 m
Overall length	0.9 m	1.9 m	2.8 m	2.1 m
Cruise speed	70–90 kmh^{-1}	110 kmh^{-1}	90 kmh^{-1}	90 kmh^{-1}
Endurance	90 min (battery)	8–10 h (fuel)	6 h (fuel)	4 h (fuel)
Maximum altitude	3,000 m	4,000 m	5,000 m	3,000 m
Payload	1.5 kg	2.0 kg	5.0 kg	5.0 kg
Wind tolerable	10 ms^{-1}	12 ms^{-1}	14 ms^{-1}	12 ms^{-1}
Launch	Catapult	Runaway	Runaway	Runaway
Landing	Belly/Catch Net	Runaway	Runaway	Runaway
Range of flight	3,000 m	60,000 m	30,000 m	30,000 m
Cost	$35,000	$47,000	$70,000	$60,000

Blimps float with the help of helium (gas with lower densities than air). The propulsion motor placed in separate nacelles in their gondola enables them to move. In order to allow asymmetric thrust to be applied for manoeuvring, the propulsion motor is mounted towards the sides of the envelope, located away from the centre line gondola (Abdul Kadir et al. 2012). Blimps can take off and land vertically without using runways (Al-Jarrah et al. 2013).

As for the dimension of the device, it is interesting to note that blimps come in various sizes; small ones for indoors applications, and large ones for outdoors applications. Blimp is also known to have lower resistance to wind. It is also relatively easy to be operated due to the reason that it operates with low flight speed as it is always in floating condition when filled with helium gas. Comparatively, the blimp is considered far more user friendly than any other types of UAV. The payload capacity of a blimp is however quite small depending on its size (Nitta et al. 2017).

Blimps are rather popularly used in a number of environmental remote sensing applications involving information collecting and interpreting process on land, oceans and the atmosphere. Among the example of the successful usage are; remote sensing towards the prediction of weather, tracking go of hurricanes, inspection of coastal dynamics, discoveries of pollutants, as well as mapping of coastal land that include forests, agriculture, tidal wetlands, and urban areas (Milstein 2011).

Conventionally, satellites are commonly used for remote sensing while aircrafts, in order to obtain similar observations are operated with human crew. However, both alternatives are not cost effective as satellites require a huge investment while manning aircrafts with human crew also adds to the initial cost of the project. Regrettably, blimps also have problems during flight, since they are very sensitive to winds (large problems arise with wind speeds higher than 10 kmh^{-1}). The best suitable application of small blimps is mainly for indoors usage. Some examples of blimps are shown in Table 3.

3.4 Helikites

Helikite is a device associating a combination of helium air balloon with kite as its wing which makes them lighter than any other air devices (Klemas 2011). Helium gas allows the balloon to launch easily even in windless weather conditions, while the kite feature works effectively in the presence of wind. To operate the device, it must be first lifted up in the air to achieve higher altitudes than the pure helium lift. Accelerating wind speed improves the helikite's lifting ability. Next, the wings which are attached to the balloon counteract any unstable characteristic of balloons and blimps in windy conditions, which consequently stabilize the helikite (Verhoeven et al. 2009).

Among the reasons why helikite is preferred to be used is because of its ease in lifting process since it can effortlessly carry payload in windless conditions. The reason behind the increment in payload capacity is the stabilization of the balloon

Table 3 Examples of blimps

Model	6 m RC Blimp	7 m RC Blimp	10 m RC Blimp	12 m RC Blimp
Wingspan	1.7 m	2.0 m	2.2 m	2.1 m
Overall length	6.0 m	7.0 m	10.0 m	12.0 m
Cruise speed	50 kmh^{-1}	50 kmh^{-1}	50 kmh^{-1}	60 kmh^{-1}
Endurance	60 min (battery)	60 min (battery)	60 min (battery)	70 min (battery)
Max altitude	100 m	150 m	300 m	400 m
Payload	2.0 kg	2.5 kg	5.0 kg	6.0 kg
Wind tolerable	5 ms^{-1}	5 ms^{-1}	7 ms^{-1}	10 ms^{-1}
Launch	VTOL	VTOL	VTOL	VTOL
Landing	VTOL	VTOL	VTOL	VTOL
Range of flight	100 m	150 m	300 m	400 m
Cost	$7,200	$8,800	$14,500	$35,000

by the kite section in windy conditions (Klemas 2013). On top of that, the cost of the helikite is considered low, which makes it one of the most cost effective UAV for any suitable types of aerial monitoring. The helikite is best known for its capacity in usage during multi-altitude and has high spatial resolution system (Marris 2013). For an example, the standard helikite is capable of flying up to an altitude of 1.2 km and at the same time carries a load of up to 5 kg. The latest invention of helikites comes with a diameter of 3 m, which makes them among the lightest aircraft balloons (Kushida et al. 2009). That being said, the stability of the helikite depends on the kite section which constantly prevents the helikite from getting bounced especially during windy conditions.

Helikites are mostly chosen for short time site-based monitoring because it can provide quick response to events and also due to its capability to acquire high temporal resolution imagery whereby the system is able to record images within desired time span (for example one day versus one week). The combination of helium balloon with non-metric digital singe reflex camera and additional surveying methods allows low altitude photogrammetry to be efficiently produced, resulting in the high quality outcome in mapping the selected small and medium size areas (less than 2.5 km^2) of interest (Mozas-Calvache et al. 2012). Conventionally, the images obtained using helikite often comes with irregular geometry, which has always been the main challenge. This is caused by wind effect and lack of flight control which generates high imprecision in camera sensors that cause the block pattern with irregular image.

One of the reasons why helikite is mostly favoured is because it can be modified according to required specifications. Sensors that can be fitted onto the helikite includes thermal infrared camera, digital camera, inertial measurement unit, GPS equipment and various other sophisticated equipment (Pereira et al. 2009). On top of the benefits listed above, it is also relatively straightforward and fast to deploy the helikite. Among successful application conducted using the helikite was the mapping of coastal plumes using temporal and spatial resolutions of the obtained images. The images were utilized to analyse and study of the evolution of coastal plumes and wetland changes (Lechner et al. 2012).

White and Madsen (2016) presented a high-resolution aerial images using a helikite at 100 m altitude which were used to develop a detailed flooding model. The research took place at North Inlet estuary, South Carolina and derived a spatially comprehensive map of ecological zones at the headwaters of a small tidal marsh creek situated at a forest marsh boundary. In order to identify ecological zones, the researchers constructed photo mosaics obtained from helikite imagery over a 150 × 100 m area using automated, maximum likelihood classification. At the same time, by using imagery assessed by helikite and GPS, they also developed a digital terrain model with ±2 cm overall vertical accuracy, mainly from waterlines at known tide height. These methods are proven to be cost efficient and simple implementation methods for studying processes that take place in marsh where accessibility is strenuous. It is essential to note that their study have proven that balloon aerial photography is indeed an effective and inexpensive way to measure important time dependent processes in marshes such as flood that are currently understudied due inaccessible field conditions.

A study conducted by Al-Halbouni et al. (2017) presented the first low altitude (<150 m above ground) aerial photogrammetric survey using a helikite balloon at the sinkhole area of Ghor Al-Haditha, Jordan. The survey provided qualitative and quantitative analysis of a new, high resolution digital surface model (5 cm px^{-1}) and orthophoto of the area (2.1 km^2). The findings show that it is crucially important to rely on correct georeferencing and reliable subsequent DSM analysis for equal dispersed distribution of ground control points in the survey area. It is important to note that the high resolution DSM and geomorphological analysis are highly relevant for subsidence and sinkhole hazard as well as precursor assessment along the eastern coast of Dead Sea. Even though helikites are tethered to the ground, it is sufficient to mention that helikites satisfactorily assist in data acquisition for long term period monitoring due to the fact that they do not require

Table 4 Examples of helikite

Model	6 m^3 Skyhook	7 m^3 Skyhook	9 m^3 Skyhook	11 m^3 Skyhook
Wingspan	2.14 m	2.44 m	2.74 m	2.90 m
Overall length	3.35 m	3.5 m	3.57 m	3.66 m
Cruise speed	Tethered via dyneema cable from the ground			
Endurance	Depends on sensors and gimbal battery only			
Max altitude	1,500 m	1,600 m	1,700 m	1,800 m
Payload	2.7 kg	3.2 kg	4.0 kg	5.5 kg
Wind tolerable	17 ms^{-1}	17.89 ms^{-1}	18.77 ms^{-1}	17.89 ms^{-1}
Launch	VTOL	VTOL	VTOL	VTOL
Landing	VTOL	VTOL	VTOL	VTOL
Range of flight	Stationary at one hovering point (due to tethering)			
Cost	$2,500	$2,555	$3,000	$3,450

motorized power to lift compared to fixed wing and rotary wings, thus making it a high endurance and most suitable platform for monitoring. Table 4 shows some examples of helikites.

4 Aerial Platform Selection Criteria

From the overview of the literature, the comparison between UAVs are made and shown in the Table 5.

Depending on their sizes, most of the aerial platforms are capable to carry high capacity of payload. In terms of coverage area, fixed wing UAVs present the best option since they are equipped with greater cruising speed and endurance, allowing them to stay longer in the air and travel further for a data acquisition mission. Other types of UAV such as rotary wings and blimps have short durations of flying endurance and made worse with limited lifespan of batteries. Helikite however, has high endurance to fly as it uses helium as its lifting force which allows it to stay afloat longer compared to fixed wings UAV. From the finding, it is noted that most aerial platforms are incapable to operate in various weather condition as they have low tolerable wind speed resistance. Helikites however, has the all-weather operation capability.

Previous researches showed that fixed wing UAV has rigid wing constructed with predetermined air foil that allows the device to fly through the airlift concept, which happens due to the UAV forward movement. They have a simpler structure compared to rotary wings, requires uncomplicated repair work and maintenance process thus enabling fixed wing user to possess higher operational time with lower

Table 5 Comparison between aerial platform reviewed

Criteria	Rotary wings	Fixed wings	Blimps	Helikite
High payload capacity	√	√	√	√
Wide area coverage		√		
Extreme endurance		√		√
High altitude	√	√		√
All weather operation				√
Autonomous operation	√	√	√	
Easy operation	√		√	√
VTOL ability	√		√	√
Inexpensive cost	√		√	√
High wind tolerance				√
Suitable applications	Inspection Detection Surveying Mapping	Surveying Mapping	Monitoring Surveillance Inspection Detection	Monitoring Surveillance

operational cost than rotary wing user. Other than that, the simple structure of fixed wing design has proven to provide efficient aerodynamics, thus giving it long flight duration advantage which at the same time making it possible to execute surveying and mapping tasks on larger area. With that benefit, fixed wing is proven to be more suitable for aerial mapping than rotary wing UAV. However, it is also essential to note that fixed wings performance is restricted on its dependency on a runway or a launcher to facilitate take-off and landing, which eventually affect the payload weight that can be carried by the fixed wing UAV.

On the other hand, rotary wing does not require forward thrust in order to initiate the movement of the flight, although technically the rotary wing functionality is similar to the fixed wing. Instead, rotary wing flight movement is initiated by their rotor blades' constant rotation that creates the air movement over their air foil which generates the lift. Rotary wing UAV has more complicated mechanical structures than the fixed wing UAV. Furthermore, the rotor copter is known to have lower range of flight with most of them only have at most several minutes' flight time, depending on the load capacity. In spite of that, rotary wings have advantage on their capability for VTOL and landing protocols, as well as the ability in agile manoeuvring and hovering ability. Due to the fact that rotor copter is able to maintain visual on a specified target for a long time, they are highly recommended for conducting local inspection tasks. Moreover, the VTOL procedures was intentionally developed to solve problem faced by the fixed wing UAVs as they require runaway or launcher for take-off.

Blimp is known for its low-flying, short-endurance and slow moving feature, which is seemly to accommodate a monitoring platform at a target location intended for monitoring and surveillance. Among the advantages of using blimps is it does not require excess fuel or battery like other types of aircrafts to fly since it is operated using helium gas, which is lighter than air thus enabling the blimp to float using the buoyant force. The shape of the blimp is also proven to be the most economical and can be efficiently used because of its light condition, appropriate for wind conditions less than 10 kmh^{-1}. Due to the fact that the unmanned blimps cost less, they are more popular to be operated. In commercial use, the most used types are blimps with small-frontal aerial photography. The payload capacities depend on the size and type of the blimps. In terms of its stabilization during flights, it is achieved by using four rigid tail fins, and also with the help of multiple attachment points positioned along the keel, which helps to allow the fastening of the camera system weight up to 1.5 kilograms.

Helikite can easily carry payload in windless conditions. The functionality of helikite in windy conditions is based on the stabilization of the balloon by the kite section, which increases its payload capacity. Among the obvious benefit of helikites is low in price, making it a cost effective platform for aerial monitoring. Helikite is known for its durability since it is able to stay in the air for several weeks at a time. Recently, helikites are highly sought after in monitoring projects since they operate in various kind of severe weather conditions, be it windy, stormy or heavy rains. Further to that, helikites are also able to reduce camera shaking because their platforms are more stable. The position of steady camera is critical during environmental monitoring because stability enhances quality and avoid the loss of expensive digital cameras as well as other equipment from falling. Apparently there is not much requirement for technical knowledge to operate helikites as it is known to be operable within minutes of training. Besides, safety precautions in using the helikites are quite minimal. As for the wind speed performance, while most UAV are only able to fly in windy conditions at 14 ms^{-1}, helikites can fly at up to 18 ms^{-1} wind condition.

5 Conclusions

The use of aerial platform technology coupled with remote sensors made it possible to achieve many tasks. The type of task or applications that suitable for an aerial mission is highly depends on the limitation criteria as been highlighted in this review. The reviews discussed in this paper also indicate that most of the studies did not investigate the capability and potentiality of aerial platforms specifically their performance under various weather conditions, such as heavy rainfall and windy condition. Thus it is important to highlight that it provides a gap to be explored in terms of which instrument or device is capable to be operated under such circumstances to acquire real time data within certain amount of period continuously. From the findings stated in this paper, the opportunity to explore the type of aerial platform that can perform under various weather conditions does exist and requires attention. Based on the results, the helikite is found to be suitable for the task of real time monitoring in various weather conditions due to its capability to operate under rough situations. However, it is also essential to note that helikite lacks in mobility and may only cover small area during its operation, but this would give higher spatial resolution and temporal data in a local area prone to the flood event. For future works, this research will seek on testing the reliability of helikite to perform in adverse weather condition.

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