Strategic framework of using drone in cities disaster response

Zahir H.[1*], Fathi M.S.[2], and Tharima A.F.[3]

[1]Malaysia-Japan International Institute of Technology, Universiti Teknologi Malaysia, Jalan Sultan Yahya Petra, 54100 Kuala Lumpur, Malaysia
[2]Razak Faculty of Technology and Informatics, Universiti Teknologi Malaysia, Level 7, Razak Tower, Jalan Sultan Yahya Petra, 54100 Kuala Lumpur, Malaysia
[3]Fire and Rescue Department of Malaysia, Planning and Research Division Fire Research Centre, Lengkok Teknologi Kawasan Perindustrian, Enstek, 71760 Nilai, Negeri Sembilan, Malaysia

*Corresponding author e-mail: zahirhassan@gmail.com

Abstract. Drone technology has been around the world more than a decade and the application has becomes more vital, especially, during the disaster event such as COVID-19 pandemic. However, some of the countries were not ready in implementating the technology due to various reasons. Thus, this study intended to identify the technological and legislative aspects of drone application for disaster response in cities environment and to propose strategic framework on optimization of drone capabilities in cities disaster response. The literature search has been conducted in order to explore the applicability of drone technology in disaster management and disaster response. Later, further investigations were carried out using the Participatory Action Research (PAR) approach. In the PAR method, the data were collected in two phases; 1) observation and discussions and 2) interview sessions. The observation and discussions were conducted to obtain the implementation process of using the drone during the disaster event by the rescue team via recorded video. To triangulate the information gathered from the discussion, a series of interview had been made. Where, six selected stakeholders from end-user, regulatory agency and supplier were interviewed. It is found that the implementation of drone technology framework in disaster consists of six perspectives, namely; actions, internal organization, external environment, needs specification and feasibility analysis. To make the framework works, stakeholders are required to function in a cohesive and collaborative manner as illustrated in the Harmonization Triangle. The strength of cohesion and collaboration has also opened up future study for a full scope disaster management cycle phases, known as response, recovery, mitigation and preparedness.

1. Introduction

Disaster response requires accurate,quick and fast decisions and actions. The complexity and strenuous process working in a very uncertain and dynamic environment complicates the situation even further. Although disasters may have similarities but each disaster has its own uniqueness due the circumstances, geographical area and the extent of the devastation. Whatever the circumstances and situation, it may be, immediate and real time assessment of the disaster site conditions has to be undertaken. However, under some situations the

assessment is hampered due to limited or no physical accessibility and/or safety risk considerations.

To overcome the constraints and limitations, one of the fast developing sectors is to deploy drones in disaster management including to support situational awareness [1]. In this review when drone is mentioned, it is to include Unmanned Aerial Vehicles (UAVs), the Unmanned Aircraft(UA), Unmanned Aerial System(UAS), Remotely Piloted Aircraft(RPA) or Remotely Piloted Aircraft System(RPAS)[2]. Cybersecurity, privacy, public safety and forensic are some of the challenges in urban setting[3].

The steep development in manufacturing and use of drones has become a major challenge in setting up the regulations of its usage. This is indeed challenging for regulators, policy makers and legislators[4]. Thus, positioning correctly human values in the age of technology and filling or closing in the gaps between admiration of technology and deep disorder[5]. The constraints in using this technology in disaster response is dependent on external and internal factors[6].

The objectives of the study was to identify the technological and legislative aspects of drone application and to propose strategies on optimization of drone capabilities in cities disaster response. Various questions were addressed including what are the advantages and constraints in using drone technology in disaster response; what are the laws/regulations/policies in place in Malaysia that hinders and/or facilitate the use of drones and what are the drone technologies available for disaster management, especially for disaster response purposes?.

Hence the scope of this paper is threefold; to analyze the current state, to identify and analyze the cause and effect for each and every limitation and constraint and to propose strategies optimizing drone technological potential for disaster response in cities.

2. Literature review

Five broad areas of Literature review were carried out namely disaster, drone technology, disaster management, disaster response, and Drone Application for flood disaster.

2.1. Disaster

The United Nations (UN) International Strategy for Disaster Reduction Secretariat (UNISDR) define disaster is a dangerous, unbearable and serious disruption of community functionality during normal circumstances and unable to deal the situation with their own readily available resources may it be human, economic, material or environmental losses and impacts.

Drones have been used to evaluate the impact of the natural disaster for decades. After the 2008 Wenchuan Earthquake, drones equipped with sensors were used by disaster responders to assess the extent of the damage caused by the earthquake. Drones were deployed to inspect the damaged at the nuclear reactor plant during the 2011 Fukushimi Dalichi crisis in Japan; Typhoon Haiyan in the Philippines in 2013 [7], [8]; the aftermath of the 2015 Cyclone Pam in Vanuatu and the 2016 Nepal Earthquake[9]. The use of drone drones in disaster response in Malaysia also greatly reduce the risks to responders and expense of the missions. The use of drones for disaster, collecting spatial data compared to other remote sensing platforms is much lower , with a greater ability to fly under cloud cover and able to collect an extremely high resolution both video and imagery data[10],[11]. In a study conducted[12] has concluded that majority of the public seems to have a good understanding of drones and their capabilities, however, the acceptance levels of drones did significantly differ depending on the context of use.

This can be achieved by having first responder drones deployed prior to the arrival of the human first responder to the crisis site or location. Thus, the first responders are equip with critical data and information upon arrival to the accident or disaster area. This would enable precision decision and action taken by the search and rescue team[13]. Drones can also provide communication gateways between first responders during disaster response at various locations of the disaster affected areas[14].

2.2. Drone technology

Significant development in drone technology and capability in recent years. The features of drones for emergency responses should have the following capabilities depending on the disaster specific, condition and geographical locations. Technologies have the potential to facilitate disaster responders with more precise damage assessment and reconnaissance. Technologies lessen the time to process the data and the analytical work of the data collected. Various types of sensory or non-sensory payloads can be attached to the drones. The maximum altitude, flight duration, flight range, and maximum payload are generally determined and influence by the weight, the model, and the energy source of a drone[15].

Data and information security and also stability and reliability of the internet connectivity as are some of the issues that requires countermeasures, a high and safe proof encrypted and protected server and platform is required. The failure of network infrastructure or the internet connection may lead communication gap, which in turn may lead to catastrophic results and affects[16]. There are three major developments in drone technology, namely miniaturization, autonomy and swarms[15]. The most significant development is miniaturization that are smaller, lighter and cheaper. Furtherance to the development of a more autonomous drones, the next level of development is the capability of drones operating in swarm or operating as a squadron of drones[15].

2.3. Disaster management

Moving forward from Hyogo Framework for Action (HFA) 2005-2015, Integrated Disaster Management(IDM) has moved forward to increase its capacity and reduce vulnerability through the The Sendai Framework for Disaster Risk Reduction(SFDRR)2015-2030 by introducing 3 positives changes compared to HFA**.** 3 positive changes are from saving lives to saving lives and livelihoods, investment for disaster risk reductioand in case of unfortunate disaster, Build Back Better

SFDRR has set out and identify 7 targets for disaster risk reduction (1) reduce number of death, (2) reduce the number of affected people, (3) reduce economic losses, (4) reduce damage to critical infrastructure, (5) more countries formulate national and local strategies, (6) develop and increase international cooperation, and (7) enhance access to disaster information. These positives changes and 7 intents of SFDRR, will be empowered further and achieve societal goal shared by all relevant stakeholders with the integration of research into implementation via Transdisciplinary Approach(TDA). The challenge is to get all relevant stakeholders from all disciplines and sectors working together. To achieve this, it is prime important to get the buying in from all stakeholders the need for a holistic and transformative solution possible.

On a broad framework, disaster includes earthquake, tsunamis, volcanic eruptions, floods, cyclones, hurricanes, landslides, bushfires, droughts, pandemic, epidemic, accidents and civil unrests. Each of the disaster has its own extent of impact pending on the respective circumstances and community preparedness, vulnerability and resilience.

Having a multi stakeholder involvements in every phase of disaster management(Mitigation, Preparedness, Response and Recovery) will ensure effectiveness in reducing the impact of the disaster by reducing our vulnerability and increasing our capacity. The Disaster Management Phases model helps to address issues related to disaster preparedness, and also business and economic recovery after a disaster. Each phase is unique but yet it is connected and has particular needs, requires definite and specific tools, strategies, and resources under various challenges.

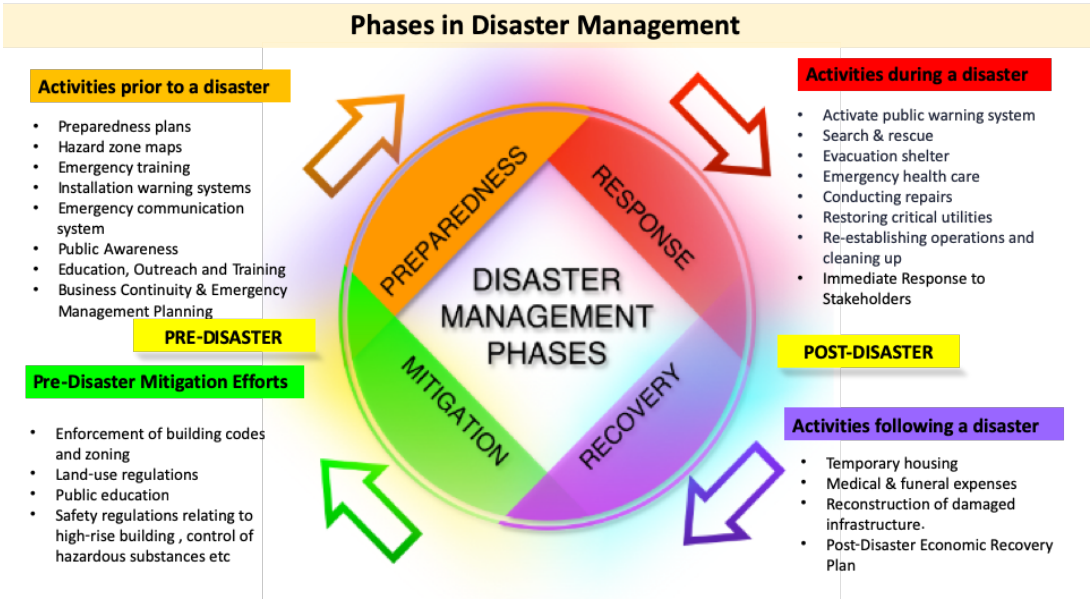

Figure 1. Disaster management phases

The Disaster Management Phases model as in Figure 1 facilitate to understand the relationship amongst the multi stakeholders, multi-dimensional and multi facet scenario. In our effort to increase resilience and reduce vulnerability of the community in facing disaster, mitigation measures requires to be indentified and implemented. This involves making changes and improvements in the non-structural and the structural measures. The next Disaster Management phase is the preparedness phase. The preparedness phase focuses on understanding how a disaster might impact the community and how education, outreach and training can build capacity to respond to and recover from a disaster. This may include engagement with the business community, joint pre-disaster strategic planning, and other logistical readiness activities. As for the response phase, as being the core and focus subject matter, it will be elaborated further in the later part of the paper. Recovery phase of disaster management cycle inclides restoration works on damaged and impacted livelihood on a community are to be undertaken as soon as disaster subsided and to build back better.

2.4. Disaster response

This phase immediate after disaster occurs, typically characterized by the need of a large set of tasks to be undertaken and coordinated with multiple resource requirements and time pressure[17].The scientific and technological input in decision making in line with the TDA is crucial for an accurate and effective decision making during the critical moments during the disaster.

Humanitarian logistics or logistic activities in disaster response comprise of planning, executing, control, monitoring and coordinating in the most efficient and cost-effective arrangement to receive and distribute relevant information, goods and materials from the point of origin to the rightly beneficiaries at the specified time and location. Thus, drone is preferred and applicable as the last-mile means of transport to overcome and made distribution possible to areas that have been cut-off and inaccessible. Although limitation of its lifting capacity, the delivery of light-weight multiple relief packages, including vaccine, water purification tablets are made possible via drones to remote or inaccessible locations within a disaster effected area[18].

2.5. Drone application for flood disaster

The application of drones combined with photogrammetry software has made it possible to collect high-performance spatial data and build-up spatial database, thus creating a high-resolution Digital Surface Model(DSM) of 22.6 cm per pixel[19]. Flood assessment can be carried out by using remote sensing technology, combining data and information obtained through satellite and Full Motion Video(FMV) via drone. Integrating FMV with appropriate software such as would be able to analyze the Geographic Information System(GIS) collected to produce critical and relevant outputs for disaster responders to consider and decide accurate, effective and efficient flood mitigation plan[20]. The 2014 worst flood disaster ever since 20 years in Malaysia has opened up the push and realisation to the need to improve the search and rescue operations by incorporating drone technology in the operation. The use of drone reduces cost and a shorter respond time and cost. Due to its relatively smaller size and ease of its deployment into disaster site very quickly as drones are expendable in relation to human life[21].

3. Research methodology

The research will be undertaken based on the methodology framework as shown in Figure 2 below. The study began with introducing the subject matter by identifying and establishing the problem statements, objectives and scopes of the research. The next phase will be the desktop literature review. In this research the Participatory Action Research (PAR) approach adopted. Next, critical evaluation, analysis of findings and identifying gaps for future study will be discussed before making recommendations and conclusion.

3.1. Research framework

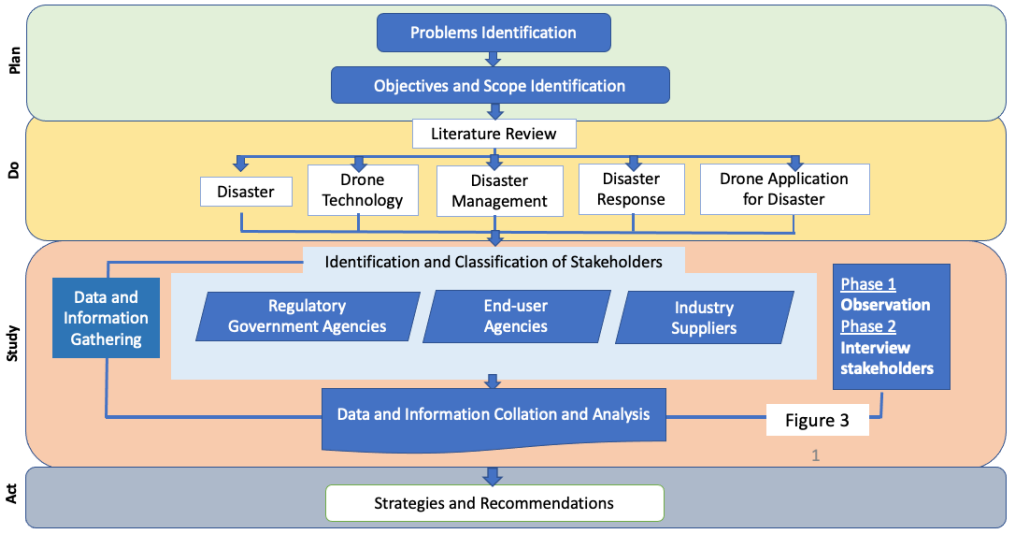

Figure 2. Research methodology framework

It is thought that the qualitative method is most suited as the method and techniques that integrate the oberservation, collecting, collating, documenting, analyzing and interpreting features, forms, elements and values of human experiences[22].

3.2. Participatory action research (PAR) approach

Participatory Action Research (PAR) approach has been chosen since the expected outcome seems to be more sustainable by getting the participation of all relevant stakeholders especially the community in every phase of the study towards the formulation of practical policy and best practice. It is hope that equitable participation would lead to a social transformation and change for the better[23]. In this context, the approach will create close bonding relationship that will close the gap between the interviewer and interviewee, the researcher and researched[24]. PAR approach attempt to bridge between science and practice, combining the

best of the two. PAR facilitates people in a community to co-discover, co-design and implement solutions to the problems and challenges of their community.

3.3. Respondent criteria

The assessment was based on interviews and review data and information made available by regulatory body, government departments and industry suppliers. The findings were then systematically and effectively evaluated.

3.4. Stakeholder engagement

The stakeholders participated in this study were from end-user agencies, regulatory body and industry suppliers. The end-users are disaster response agencies that provide services to various types of disaster. The regulator is the government agency that regulate all civil aviation matters under the Ministry of Transport Malaysia. While the industry suppliers are supplier of drones and also all related technology that comes with it.

3.5. Two(2) phases research approach

Figure 3.3 below shows, the two phases of the research approach. The approach has been adopted as an alternative or second best option to the required oberservation and discussion on actual operation, training and simulation drill. In the first phase, observations and discussion were made on the selected videos. While the second phase were a series of interviews conducted via Zoom video conference.

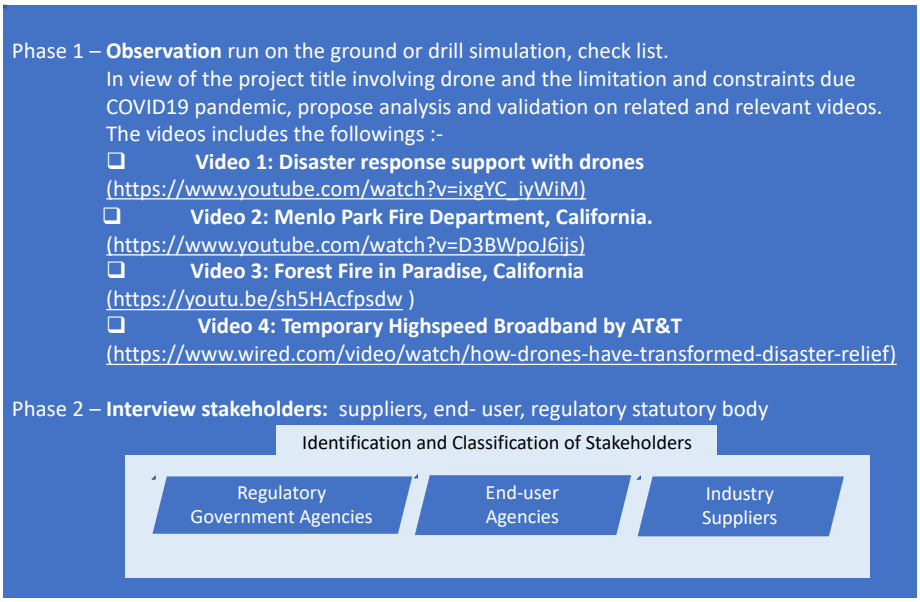

Figure 3. Phases in research approach

Each interviewee were asked three main and central questions namely issues of the current state of drone used in disaster management, the causes and effects for each and every limitation and constraint in operationalizing drone and how to increase in awareness on the need and optimizing drone technological potential for cities disaster management.

4. Result and finding

4.1. Observation and Validation on Operational Matters

In view of the COVID19 pandemic and the Movement Control Order(MCO) which is still inforce at the time the research being written, an alternative approach is to make observation on relevant videos available on youtube. These videos were also shared with interviewees prior to their interview session for their comments and validations, wherever possible.

Similar experiences were reported on a colloborative SAR operations consist of multiple drones by multiple operators including hobbyist, media together with rescue agencies. Observation and validation on operational matters were shared by the four(4) end-users responders.

4.2. End-user perspective

This section discusses the current state of key end-user agencies implementing drones within the response phase of disaster management. From the data collected from the interviews conducted, it shows that the drone unit of these agancies was set-up quite recently, the ealiest was in 2016. The drone fleet of the agencies are quite basic having minimal and limited in terms of numbers and capabilities to just having camera for taking photos, videos and thermal detection payloads. While very limited budget allocation for the procurement of the drone fleet. Training of drone operation is limited that comes together with the procurement of the drones and conducted by the suppliers.

4.3. Drone technology

As from the industry players perspective, it is impotatnt to realized that drone based solution is 30% flying or operating drone while the other 70% is the analysis of the collected data by the drone. The combination and integrating these two(2) broad skill sets have been proven and agreed upon through the literature review, observations and interviews conducted.

4.4. Drone regulation : present and future

The custodian and regulatory authority to ensure the safety of Malaysia air space is the Civil Aviation Agency Malaysia(CAAM). CAAM has plan for future Regulations and Directives targeted to be enforced in 2022. The 2022 regulations and directives will be a migration from classification based on weight, classification base on the risk factor namely open(Low risk), Specific(Medium risk) and Certified(High Risk) categories. It will also include regulation for operator registration and direct remote identification.

5. Discussion

Based on the findings under the research framework, in every identified and relevant disaster response operation, firstly to identify critical actions required to incentive technological adoption of drone capabilities in disaster response and secondly to set strategic operation framework aims to guide disaster response agency throughout the adoption of drones.

5.1. The six facet perspectives

The dynamics to the discussion is summarised by the six facet perspectives namely actions, internal organization, external environment, needs specification, feasibility analysis and implementation, as shown in Figure 4. The core of all the the six perspectives lies with the three (3) main players namely the the end-user, technology provider and regulator. In turn, these three (3) players are required to function in a cohesive and collaborative manner in order to ensure their respective role is played effectively as illustrated by the Harmonization Triangle in Figure 5.

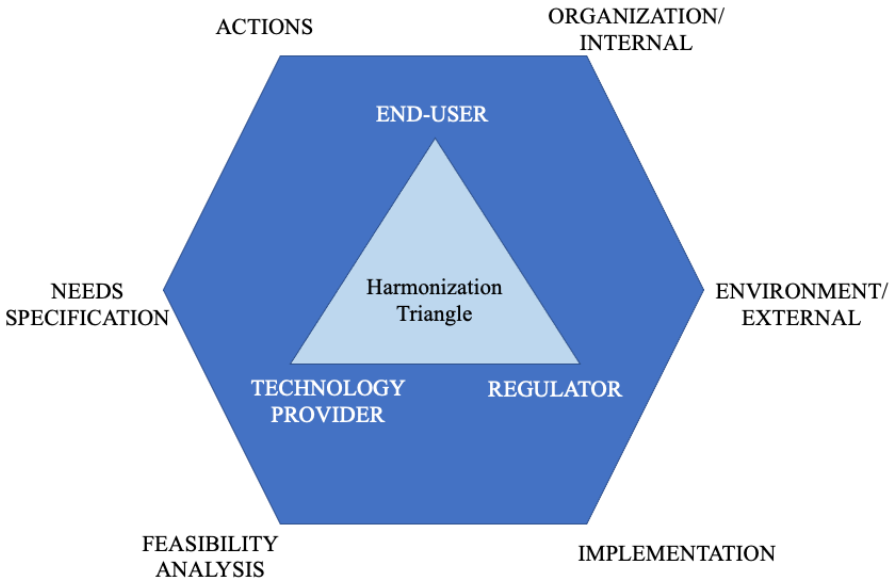

Figure 4. Six facet perspectives

Leadership quality, technology awareness and staff training to justify the procurement of drones are part of **internal organization** issues while statutory regulatory agency and industry players are some of the **external environmental** issues. In the **implementation** stage, is to ensure the most optimum drone capabilities and related technologies are identified, determine and procure correctly and accurately that leads to determination of the **needs specification.** Finally to carry out the **feasibility analysis**. All this requires **actions**.

5.2. Harmonization triangle

The Harmonization Triangle illustrate the interaction between all the three sectors on the various common interest and strategic issues. The inter and intra harmonization of the regulator, end-user and industry supplier would guarantee a brighter future in optimization of drone capabilities in disaster response.

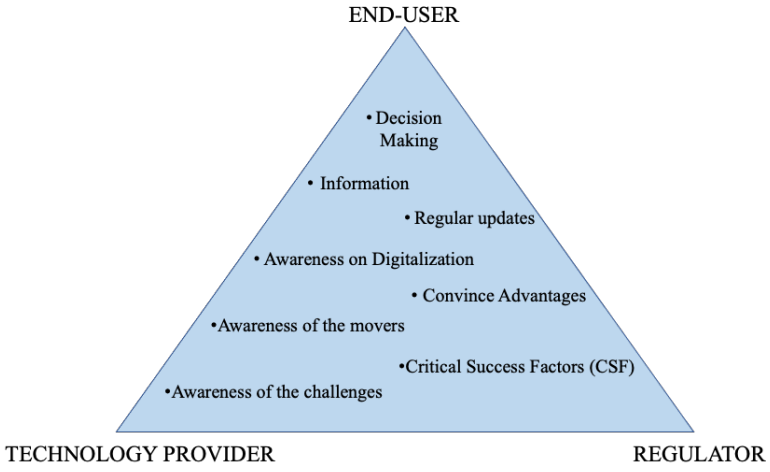

Figure 5. Harmonization triangle

5.3. Strategy management process

The outcome from the research, can then be used as basis to continue with the strategy management process as in Figure 6**.** Identified strategic issues and the strategic framework can then be used as basis to continue with the full and complete strategy management process.

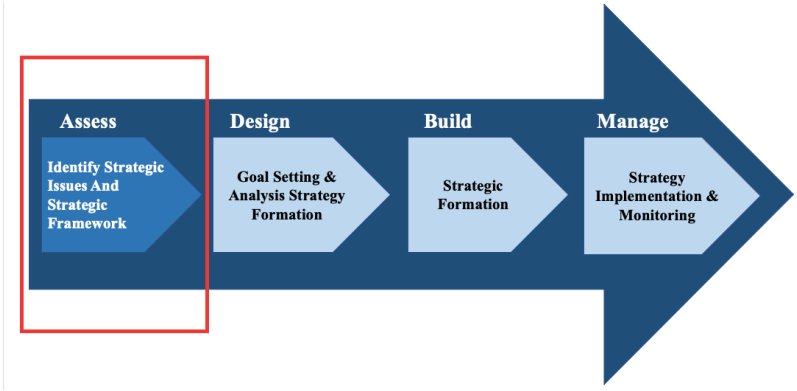

Figure 6. Strategy management process

6. Recommendation and conclusion

The proposed strategic framework consists both non-structural and structural framework. The strategic framework on the optimization of drone capabilities in cities disaster response lays the foundation to continue with the design, build and manage of the strategy management process. The inter and intra harmonization of the regulator, end-user and industry supplier would guarantee a brighter future in optimization of drone capabilities in disaster response.

This study focuses on the response phase of disaster management cycle. To evaluate the implementation of drones in the full scope of the 4-phase disaster management cycle namely response, recovery, mitigation and preparedness is an option for future research.

References

[1] Zwegliński T. *The use of drones in disaster aerial needs reconnaissance and damage assessment-Three-dimensional modeling and orthophoto map study. Sustain* 2020;12:1–20. https://doi.org/10.3390/su12156080.

[2] Sarrión Esteve J, Benlloch Domènech C. *Rights and Science in the Drone Era Actual Challenges in the Civil Use of Drone Technology.* Rights Sci R&S 2017:117–33.

[3] Vattapparamban et al. *Drones for Smart Cities: Issues in Cybersecurity, Privacy, and Public Safety* Edwin. IWCMC 2016 12th Int Wirel Commun Mob Comput Conf Sept 5-9, 2016, Paphos, Cyprus 2016:216–21.

[4] Nugraha RA, Jeyakodi D, Mahem T. *Urgency for Legal Framework on Drones: Lessons for Indonesia, India, and Thailand.* Indones Law Rev 2016;6:137. https://doi.org/10.15742/ilrev.v6n2.229.

[5] Katyal N. *Disruptive technologies and the law*. Georgetown Law J 2014;102:1685–9.

[6] Hristozov S, Zlateva P. *Concept model for drone selection in specific disaster conditions.* Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. - ISPRS Arch., 2018. https://doi.org/10.5194/isprs-archives-XLII-3-W4-245-2018.

[7] techteam. New {Use} for {Drones} in the {Philippines} {Is} {Saving} {Lives}. Impact Hub 2017:1–9.

[8] Sjaak S. *Using Drone Imagery for real-time information after Typhoon Haiyan in The Philippines* 2016:9–12.

[9] Anhorn J, Herfort B, De Albuquerque JP. *Crowdsourced validation and updating of dynamic features in Open Street Map*: *An analysis of shelter mapping after the 2015 Nepal earthquake.* Proc Int ISCRAM Conf 2016.

[10] Consulting GW, Events GW, Media GW, Us A. *Did you know Drones can be used for Humanitarian Work ?* Drones for Humanitarian Work : The United Nations Approach Mapping 2021:1–4.

[11] Soesilo Denise. *How Drones Can Help in Humanitarian Emergencies 2016*. http://www.ictworks.org/2016/12/07/how-drones-can-help-in-humanitarian-emergencies/.

[12] Lin Tan LK, Lim BC, Park G, Low KH, Seng Yeo VC. *Public acceptance of drone applications in a highly urbanized environment.* Technol Soc 2021;64:101462. https://doi.org/10.1016/j.techsoc.2020.101462.

[13] Lemayian JP, Hamamreh JM. *First Responder Drones for Critical Situation Management.* Proc - 2019 Innov Intell Syst Appl Conf ASYU 2019 2019. https://doi.org/10.1109/ASYU48272.2019.8946353.

[14] Micheletto M, Petrucci V, Santos R, Orozco J, Mosse D, Ochoa SF, et al. F*lying real-time network to coordinate disaster relief activities in urban areas.* Sensors (Switzerland) 2018;18:1–20. https://doi.org/10.3390/s18051662.

[15] Vergouw B, Nagel H, Bondt G, Custers B. *Drone Technology: Types, Payloads, Applications, Frequency Spectrum Issues and Future Developments* 2016:21–45. https://doi.org/10.1007/978-94-6265-132-6_2.

[16] Sorsaniemi A. *Internet of Things and H2020* 2014:87–92.

[17] Schryen G, Rauchecker G, Comes T. *Resource Planning in Disaster Response: Decision Support Models and Methodologies.* Bus Inf Syst Eng 2015;57:243–59. https://doi.org/10.1007/s12599-015-0381-5.

[18] Rabta B, Wankmüller C, Reiner G. A *drone fleet model for last-mile distribution in disaster relief operations*. Int J Disaster Risk Reduct 2018;28:107–12. https://doi.org/10.1016/j.ijdrr.2018.02.020.

[19] TUROĞLU H, DOLO A. the *Advantages of Drone Technology in Urban Flood Studies.* Int. Symp. Geomorphol. 2017, 2017.

[20] Sharom MAAM, Fauzi MFA, Azmi MZM, Samsudin S, Rahman MHA, Fadzil MA, et al. *Assessment And Mitigation Of Monsoon Floods Via Satellite Imagery Data Extraction And Drone Full Motion Video (Fmv).* Def S T Tech Bull 2021;14:82–90.

[21] Sobri Hashim A, Syafiq Mohamad Tamizi M. *Development of Drone for Search and Rescue Operation in Malaysia Flood Disaster*. Int J Eng Technol 2018;7:9. https://doi.org/10.14419/ijet.v7i3.7.16195.

[22] Macdonald CD. *Understanding Participatory Action Research: A Qualitative Research Methodology Option*. Can J Action Res 2012;13:34–50.

[23] Benjamin-Thomas TE, Corrado AM, McGrath C, Rudman DL, Hand C. *Working Towards the Promise of Participatory Action Research: Learning From Ageing Research Exemplars.* Int J Qual Methods 2018;17:1–13. https://doi.org/10.1177/1609406918817953.

[24] Baum F, MacDougall C, Smith D. *Participatory action research. J Epidemiol Community Health* 2006;60:854–7. https://doi.org/10.1136/jech.2004.028662.