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Research Paper

UAV Architecture for Patrolling Air in Geotourism Zone at Disaster Risk with the Characteristics of GPS Signal Limit

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Abstract

The development of geotourism is a trend in the field of tourism that is always being developed. The exoticism of natural tours in the environment of geothermal and volcanology activities will be proportioned to the potential risks that appear. The records of tracking from several countries show the fatal conditions from the effects of carbon dioxide emissions such as H2S, SO2, and CO that are emitted from unexpected geophysical activity, odorless so that they are not detected properly in geotourism zones that cause casualties of inhabitant and tourist. The aim of this paper is to provide a reference of the framework for the drone explore architecture for the requirement of monitoring in the environmental conditions of the limited GPS signal. This study implemented the Research & Development (R&D) method by using the Zachman framework. The study found that the development of the Early Warning System (EWS) as a part of mitigation using robotic technology such as the UAV drone becomes the solution requirement of the problem because the drone is capable of carrying sensors that detect harmful gases with a radius that is relatively low. The drone sensor will process the gas data with the permitted threshold gas ratio and send the collected data to the administration system. This case becomes a part of the disaster mitigation process in the geotourism field.

Keywords: *Geotourism; Disaster; Mitigation; Architecture Framework; UAV Drones*

INTRODUCTION

Indonesia has a landscape of forests, mountains, flora, and fauna that provide exoticism as a trigger attraction of tourism in Indonesia. The tourism industry has become a priority sector that is prioritized by the State in a term of building and infrastructure development. Indonesia managed to exceed the target to attract foreign tourists to reach 3.92 million in 2022 with revenues of $ 4.26 billion, which is ten times higher than the previous year (InCorp, 2023). Geologically, Indonesia traversed two major volcanoes in the world: the Mediterranean Mountains at the west and the Pacific Sirkum Mountains at the east. This is why Indonesia has many active volcanoes. The active volcanoes and geothermal are scattered throughout Sumatra to Lombok and Papua, which attained 127 mountains and 69 mountains that get intensive monitoring because of the magma activity in it. This natural phenomenon is increasingly encouraging the development of geotourism in Indonesia.

The trend of geotourism in Indonesia has grown, as in the destination area affected by the volcano disaster in Mount Merapi, a volcano of Theater Ketep Pas, sunrise at Mount Bromo, Sunset at Mount Agung Bali, and panoramic crater tour at Mount Dieng. Geotourism is a tourism concept that promotes the collaboration of travel and entertainment content that involves aspects of culture, social environment, local heritages, and ecotourism products by emphasizing an understanding of the strong local geographical character in a tourist destination. In 2002, this concept was published by Travel Industry of America and National Geographic Traveler Magazine. Then, this concept became a trend in many countries that have natural phenomena such as geothermal and active volcano activity. Some references of destinations from the Goetourism that are famed in the world are Geothermal Rotorua, New Zealand; Mount Etnain, Italy; Hawaii Volcanoes National Park; Hawaii Haleakala Volcano; geysers Yellowstone National Park; Mount

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Villarrica in Chile; Hot Springs National Park in Arkansas, Mount Fuji in Japan and Mount Tungurahua in Ecuador. In line with the attraction of geotourism, there are also invisible threats in the tourist zone that need to be watched in those areas, such as gas emissions. Volcanoes and geothermal areas are regularly linked to various gas emissions. These gases are toxic and damaging gases, including carbon monoxide (CO), carbon dioxide (CO_2), nitrogen (N_2), hydrogen (H_2), sulfur dioxide (SO_2), hydrogen sulfate (H_2S), hydrogen fluoride (HF), helium (He), methane (CH_4), and heavy metal content in the air (Heggie, 2009). Here are the characteristics of some harmful gases that become the dominant risks arising in the geotourism zone.

TABLE 1. Toxicology of Volcanic Gases

	Characters	**The Effects**
Carbon Dioxide (CO_2)	This gas is colorless, will evaporate in air (δgas) = 1.52 g / L with a normal threshold of 5000ppm / 8h. 9000 mg / m3 in air	Symptoms appear when high concentrations make the breathing rate faster and increase heart rate (at> 7.5%), headache, sweating, dizziness, shortness of breath, muscle weakness, mental depression, drowsiness, and buzzing effects in the ear. Prolonged exposure to concentrations> 10% can cause unconsciousness.
Hidogen Sulfide (H_2S)	This gas is colorless and flammable and has a foul odor. The typical smell is seen at 0.77 ppm. (δgas) = 1.19 g / L. PEL (average more than 10 minutes) = 20 ppm. 28 mg / m3 in air	Inhalation 20-150 ppm can cause eye irritation. In low concentrations, that exposure can cause headaches, fatigue, dizziness, and excitement. Exposure in very large numbers causes paralysis of respiratory central and death.
Sulfur Dioxide (SO_2)	Colorless gas with a stinging smell. The odor is sharp at 0.3-1.0 ppm and is easily visible at 3 ppm. (δgas) = 2.26 g / L. Solubility of PEL = 5 ppm in air; 13 mg / m3 in air.	Eye irritation and respiratory tract cause in burning eyes, coughing, and difficulty in breathing. Approximately 90% of inhaled SO_2 is absorbed in the upper respiratory tract, where it forms sulfuric acid. Concentration of 6-12 ppm causes sudden irritation of the nose and throat. The concentration of 10,000 ppm irritates the skin in less than 1 minute.

Some track records of the tragedy of toxic gas emission disasters in some parts of the world that ever happened in the geotourism region, as incidents in 1974 and 1873 at Vesuvius, Italy, which claimed 407 victims died because of CO_2. In 1650, there were 40 victims exposed to sulfur gas from the eruption of Ethna, Italy. In 1902, there was the tragedy of Santa Maria, Guatemala, which affected 1,500 victims in a village who died. The incident in 1677 at La Palma, Canary Islands, affected a victim, and several livestock died because of gas. In 1997, in Aso Japan, there were 7 victims who died because of SO_2, which is concentrated above 5-8 ppm. The Karthala Tragedy in the Indian Ocean in 1903, where 17 victims died because of being near the solfatar. In Indonesia, the tragedy of Dieng Plateau, Java, in 1979 became a phenomenal occurrence, with 149 residents dying because of inhaling CO_2 and H_2S that is produced from the activity of Sinila and Siglundung craters. In June 1923, three boys died because of carbon and hydrogen sulfide at the time of the eruption at Mount Tangkuban Perahu (Simkin et al., 2000). The latest updated phenomenon is the eruption of the Crater Sileri Banjarnegara. The sileri is one of the active craters in the Dieng plateau complex, which experienced a freaking eruption, such as bursts of smoke and mud that soared to a height of 50 meters. At least 20 people who were traveling at the site experienced a direct impact of injuries. Previously, the Sileri Crater eruption was the most hitting the victims. It is recorded on December 4, 1944, that Sileri Crater experienced a similar phreatic eruption. In this tragedy, at least 117 people were taken away. After the "44" tragedy, the history repeated in Sileri Crater in December 1964. A village called Jawera Village was lost because of an explosive freatik type of Sileri eruption. It is recorded that 114 people died in Sileri activity.

The threat of toxic gases in the geotourism zone is the essence of a problem that is crucial because it is invisible. It is often undetectable to the eye and odorless, but it becomes extremely lethal if it is not handled immediately and given special action. This gas will cause death in humans and animals when the concentration exceeds the normal threshold and is inhaled into the lungs. On the other hand, as it is known that the tourism zone is a destination area with many visitors, so in the point of view of physical hazards, an innovative effort from the handling and anticipation action of disaster gas in the geotourism zone is very needed and become the main problem of mitigation. The aim of this paper is to provide a reference of the framework for the drone explore architecture for the requirement of monitoring in the environmental conditions of the limited GPS signal.

The development of the geotourism trend in line with disaster vulnerability in the circum Pacific and Mediterranean mountains that cross Indonesia is still limited in mitigation studies. Previous mitigation studies on environmental and renewable energy (Zhan et al., 2021), tourism recovery against COVID-19 (Yeh, 2021), and climate change (Knez et al., 2022). Thus, the mitigation of geotourism is an attraction of this study and is in line with the research recommendation on the study (Wulung et al., 2020). The aim of this paper is to provide a reference of the framework about the drone explore architecture for the requirement of monitoring in the environmental conditions of the limited GPS signal.

LITERATURE REVIEW

Handling mitigation in tourism area can be done by promoting the availability of tools and the use of information containing natural hazard risk in the tourism sector and suppressing regulatory compliance aspects regarding the planning of using the land and the building. In the development of tourism infrastructure, it must strongly reject the development of infrastructure that is not built with the approved code (Dodds, 2007; Shekhar & Valeri, 2023). Five other aspect-based approaches are: (a) enhancing the capability of disaster preparedness from local authorities, local tourism industries and residents of the destinations that is prone of disaster for effective emergency response, (b) raising the awareness of local authorities, local residents and tourists; (c) improving the local environmental management and the capability of planning through local hazard identification, vulnerability assessment of instances in preventive measures and vulnerability mapping of high risk zones (d) establishing linkage communications to manage the potential risks between local authorities, the private sector, communities, and local populations on local disaster issues to enable the effective responses in crisis situations (e) enhancing the tourist belief in the tourism destinations (Lak et al., 2020). Conducting the mitigation process by emphasizing the continuous promotion in the geotourism destination zone is a collaborative step because it does not only concern on the aspects of safety, financial or income but also the aspect of reputation that should be concerned (Fassoulas et al., 2022).

The challenge of this study becomes unique and becomes a viable solution for maintaining the connected air connections. Hand off between UAVs is a system of specific problem, the security and UAV energy supply that is described (Erdelj et al., 2017). Limitations and lack of sensors will be key factors determining the capability of the disaster management rules that will be developed, where incidents related to the phenomena of geophysical process must be able to be identified and detected (Griffin, 2014). Several track records of using drones for handling dismantled mitigation of disaster include support for food and medical supplements, search and rescue operations and monitoring relief and operations of rehabilitation, where the role of Geographic Information System (GIS) becomes an essential tool for solving the problems in the context. When GIS is integrated with the UAV, it provides an information layer on a variety of themes that enable managers to make decisions on disaster management (Tiwari & Dixit, 2015). To develop the disaster management, it is required the equipment with the different sensors. This is a form of support for situational awareness and an assessment of information. This approach is important in the process of localizing the victims which is divided into three phases, namely crawling, detecting and relaying (Tanzi et al., 2016).

In general, the UAV approach used for air mitigation and monitoring requirement is by using pathways with mapping GPS points as patrol lanes, but the development effort of mitigation via UAV still require innovation for the need of connectivity to unmanned aerial vehicle with low altitude and signal minimal infression (Yajnanarayana et al., 2018). The UAV is offline and able to fly on specified routes to collect baseline data and provide assists in general disaster management systems (Griffin, 2014). In some countries in developing condition, GPS signals is used for guiding drones. Conventional drones without GPS signals will become unstable and lose track guidance. Signal limitations in some conditions in the geotourism zone are common, because it is on valley of mountain and niche of nature where the potential of toxic gases is exist. In the context of such cases where the signal existence is a limit, the GPS approach to UAVs becomes ineffective to guide an air patrol track as part of a mitigation instrument.

To understand the position of this research related to the development of "disaster drones" in a relative position, the following is the track record of actual research that has been carried out:

Table 1. Previous Research

No	Paper	Overview
1	(Apvrille et al., 2014)	Information plays a key role in crisis management and response to natural disasters. Previous contributions to how light unmanned aerial vehicles (UAVs) or micro drones can effectively help rescuers to improve situational awareness and assessment, however such approach is not the case with volcanic zones with limited internet signal.
2	(Lan et al., 2016)	VR and drones measure: (a) camera synchronization, (b) camera array design, (c) flight path planning, but the two drone technologies are not applied to disaster mitigation models with poison gas and temperature sensors.
3	(Hashim & Jusof, 2010)	This study explores Virtual Tourism as a destination object of Kelly's castle (Malaysia), but does not use the Cam Drone approach for Disaster Mitigation.
4	(Hermawan, 2016)	Developing a mobile media tourism framework using a Virtual Reality approach in the tourism zone, but this approach does not use drones as a disaster mitigation media variable.

From the track record of research on the three tourism mitigation domains, mechanical engineering and informatics which refers to the uniqueness of the study, namely the formation of protopite drone patrols that are used as disaster mitigation instruments in banana-prone tourism areas with limited GPS internet signal zone characteristics. The current research track record provides a clear description of the differences and relative positions of current research with actual research trends in the applied science roadmap and facts in Table-1 as well as being the state of art of this research. The aim of this paper is to develop an architecture framework of early warning system in geotourims zone using UAVs equipped with CO2, H2S, and SO2 sensors. The drone that will be developed is an air patrol instrument to detect potentially toxic gases and provide early warning at the postal administration of geotourism monitors. The novelty of this research is the pathway approach to the patrol pattern which is involved in the architecture that is as alternative option without the GPS signal to the fill the obstacles on geotourism field with the character of minimum GPS signal. The definition of architecture in UAV design is to use the Zachman framework because it provides a broad perspective, even it is from the business requirement in geotourism zones and technology lines applied to disaster mitigation systems.

RESEARCH METHOD

The method used in this study is a development research approach or Research & Development (R&D). The phase used is requirement analysis, designing and implementation. The Zachman framework is used as a tool for documentation process while the literature study is used as a reference to get the process design. Zachman framework is part of Enterprise Architecture (EA), which is a method used in building architecture system that give priority to the planning approach of data quality with the orientation on business requirement (Zachman, 2003). EA is used for providing the approach such as a method for developing blueprints, showing the effects of moving a wall, providing the plans for alteration management and helping to maintain the staff knowledge (Gerber et al., 2020). Zachman framework is a logical structure for identifying the classification and the descriptive representation systems in various perspectives and it is a simple framework. This mix method is formulated in three phases, they are as follows:

1. The requirment analysis includes the components composing the drone instrument such as the requirment of sensor instruments that will be brought and giving the impact on the scale of the drone, the requirment of power motor for the drone rotor related to the lift, the ergonomic body design and battery support that will determine the duration of flying drones in performing air patrols on the geotourism zone.
2. Designing is done after the UAV design has been set. The components are reviewed and selected which is the quality components and appropriate with the requirements system. The stages of designing system include how to build physical *pruksi*. They include the description of component layout and how to wire in system, coding platform. The design refers to the Zachman framework method that covers some aspects: What, How, Where, Who, When, and Why.

The implementation is the phase of converting the physical design to be as close as possible with the design that has been planned. The implementation phase develops the function of UAV Drone for mitigation in order to run properly and integrated with the early warning system that is developed in geotourism zone. The implementation of the drone will refer to the natural conditions in the geotourism zone of Mount Dieng and Mount Merapi at Java.

FINDINGS AND DISCUSSION

The discussion of this paper is described that there are three main stages in designing the UAV architecture for requirement of monitoring air in the geotourism zone with the character of GPS signal limit. These three discussions will cover the analysis of requirement, the design including the engineering software and implementation of interaction at the level of business and technology architecture from both requirements of designing system.

Requirement Analysis

Requirement analysis is related to the user of requirement i.e sensors, navigation and transmitter platform for EWS (Zachman, 2003): (1) sensors brought by UAV used for air monitoring support requiremment, those sensors are the temperature sensors and toxic gas sensors. The sensor carrying the drone should be measured by weight and volume, since it impacts on the need for the allowable weight tolerance of the rotor lift capacity of the UAV. Structuring the sensor layout on the board will determine the design of the scale and volume of the drone that will be designed. (2) the navigation mechanism for tracking thatt will be used in the mitigation drone, where the conventional drone drone path will be guided using the GPS path, but on special requirement, it seems the case of Geotourism in Merapi and Dieng in Indonesia, the conditions of terrain, the lack of GPS signals and flight requirement at low altitudes affected the use of GPS navigation can not be used optimally. Another support mechanism is by using an inertial navigation using a compass and the Inertial Measurement Unit (IMU). With the needs of motion sensors (accelerometers) and rotation sensors (gyroscopes), accelerometer measures the translational motion and gyro measures the rotational motion of the platform where this sensor is installed. To measure the complete object motion on six degrees of freedom (degree-of-freedom / DOF: 3 translations and 3 rotations), it is needed a pair of triad accelerometer and triad gyroscope. In one package, this combined sensor is known as flight control. Based on the way of sensing, there are two types of IMU installation, namely stable-platform system and strapdown system. Stable-platform system uses the principle of rigidity-in-space or conservation of angular momentum. The IMU on a stable-platform system does not change its orientation to the inertial framework, for example, earth, ignore the earth revolution, although the vehicle where this sensor installed is changed its orientation (eg, pitch, yaw or roll). Gyroscope is a sensor used for measuring the rotation. Based on the type of output, there are two types of gyroscope those are rate-integrating gyro and gyro rate. Rate-integrating gyro releases angular changes to calculate how many vehicles are rotating and at rate-gyro count how fast the vehicle spins. (3) the development of platform for early warning about potential threat of toxic gas emergence uses UHF 433 MHz telemetry. This is because the frequency is included in the category of civil and legal range, it is appropriate, if it is compared with IEEE 8.02g wifi, so the use of UHF 433 MHz has a wider range.

Figure 1. The sensors used for EWS System via Drone in Geotourism zone that are potential volcano disaster with characteristics of minimal GPS signal.

Designing

The design approach used the Zachman framework approach by emphasizing various aspects: What, How, Where, Who, When, and Why with a Business Conceptual, Early Warning System (EWS) and Technology (Physical Design) perspective. By emphasizing on the use of Zachman framework where a design and analysis is done together. This concept becomes relevant to emphasize the overview of the drone-based process structure mitigation that is managed and allows to include information from the player's perspective on each process and technology to be applied.

Table 2. EWS Geotourism Mitigation by Drones Architecture

	What	**How**	**Where**	**Who**	**When**	**Why**
Scope	Provide a crucial description of mitigation services in geotourism zones with potential disasters	Data collection, observation, area mapping and contacts with local residents and tourists	EWS mitigation center, geotourism location, service provider for touris	Government Ministries, Dinas in the regions, locals geotourism and visiting touris	Routine patrol and when possible drone operation by viewing gajala and natural sign	Affects the reputation of geotourism, the integrity of the country and the security of the touris in the destination place
Business (Conceptual)	Uses UAV robotic technology by ensuring air monitoring services for toxic gases and temperature increases from geophysical activities in the tourism zone.	Recapture patterns from toxic gas monitoring operations and define an effective approach to mitigation posts.	EWS operational patterns, drone patrol track layouts, geotourism locations and all activities.	Stakeholders and all participants directly and indirectly on the EWS service function: admin, pilot drone, department, locals and tourists who visited the destination.	Patrol for EWS service support at mitigation center.	Evaluate the function of the organization to improve the quality of service support, information dissemination to the local population and touris.
EWS geotourism mitigation (logical design)	Attribute detail, terminology, description of EWS drone mitigation operation service.	UML, Usecase model, methodology, drone architecture, data packet, security model, connectivity, track path, as well as transmission and communication flow	Environmental model, drone prototype test model and EWS system, test area.	Responsibilities and authorization of each EWS system admin and daily operational staff to ensure access to specific mitigation instances.	Cycles patrol route, done periodically, daily or sudden emergence of geophysical activity events.	The purpose of the EWS system is the mitigation of geotourism, the procedures used, the function and the size of the information system.

	What	How	Where	Who	When	Why
Technology (Physical Design)	Communication protocols, syntax, algorithms, descriptions of EWS drone mitigation.	Received protocol, legal system, system design, ergonomic, guideline, user manual EWS and authorozed activities.	Technical architecture, infrastucture layer development, network layer, monitoring post support facility.	Government rules on technical mitigation and legal aviation drones.	Cycles to learn about technology and related things.	Understand the details of the regulations, define the business strategies and services of organizational mitigation operations in the tourism zone.

In the physical design aspect, the main work undertaken in the development of the system is for mapping the patrol track manually, referring to the use of inertial navigation as well as on the use of patoli drones to monitor crop yields and monitor the existence of pests and maturation of oil palm plantations. This condition will require the drone to fly low, the GPS navigation approach becomes ineffective, so other navigational approaches can be applied such as computer vision algorithm domains that use visual sensors that enable guided drone patrol tracks to be applied to the technology line.

Implementation of EWS System

The implementation of architectural designs that is designed on drones should provide a balance that determines the functionality of business performance and technician performance on the system, where the applied technology architecture will drive the improvement of post-mitigation administration performance at the process level and decision-making for security service requirement in geotourism zones that ensure residents local and tourist visiting are protected from the impact of disasters such as toxic gas exposure and geothermal activity from the natural environment in the disaster prone zone. The discussion of this implementation refers to the mechanism described in Figure 2.

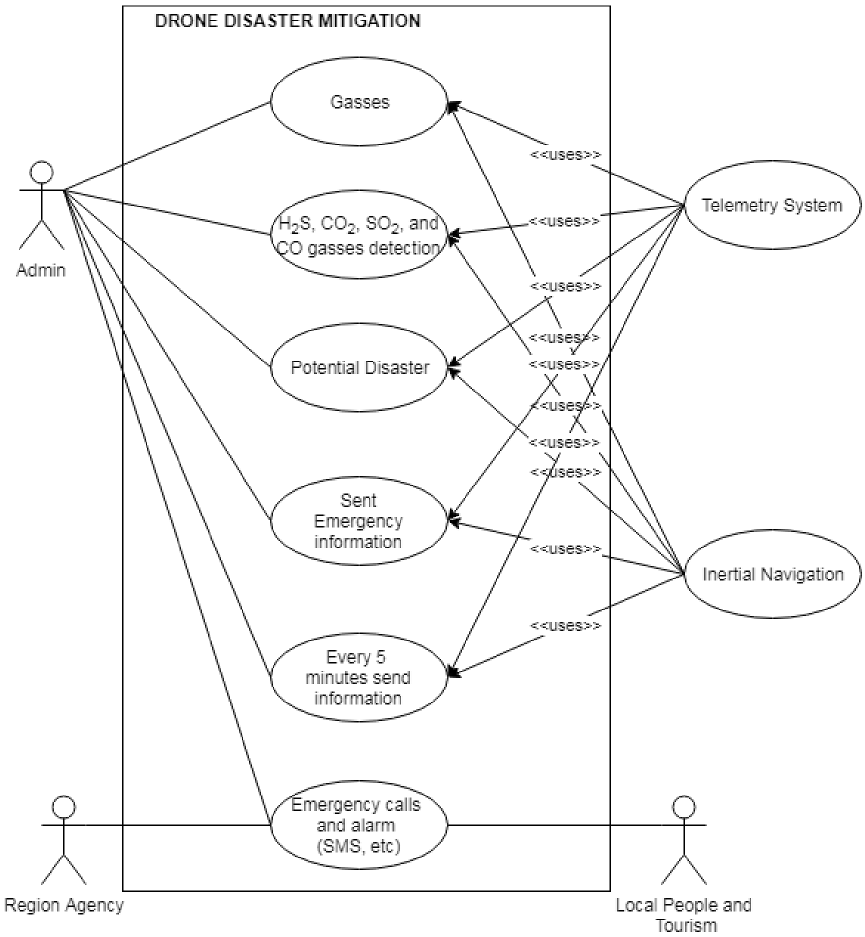

Figure 2. UML Implementation of operational mechanism EWS mitigation ecotourism via Drone.

At the relevant infrastructure drone mechanism layers layers will include the following work mechanisms: (a) identifying air pressure at the main point of the air patrol to ensure that the wind pressure variable is reliable in line with the drone rate and it is not an obstacle. (b) Establishing a mitigation post. The mitigation post is the safest location where the starting point for the drone will begin to be flown (c) the drone runs on a pathway in the form of a patrol track that is developed by using an inertial navigation approach. Referring to the condition of geotourism case in Java like Dieng mountain that is steep with the potential of gas emerging from some crater, hence detection path of gas potential of H2S, CO2 and SO2 using drone is in the form of starting line of mitigation post which then will be connected between some crater in Dieng mountains which has a dominant tendency to be the source of origin of gas emissions and is always packed with touris, and where the drone at the end of the crater will then return to the mitigation post. (d) while driving on the patrol track every 5 minutes once the drone will send the condition data of gas emission to the mitigation post through the 344 MHz UHF frequency, the data will be received by the admin on the mitigation post.. (e) the admin will process the data into information and identify whether the emission threshold is still permitted, or the status of the emission threshold has become an emergency condition. (f) the systems with the admin authorities will notify government officials and authorized officers of emergency conditions of toxic gas concentrations in the geotourism zone. (g) the information on the evacuation of zones and the evacuation of the inhabitants or visiting touris using a short message system for local residents as well as the status of information for touris regarding emergency status in the tourism zone. The approach is shown in Figure 3.

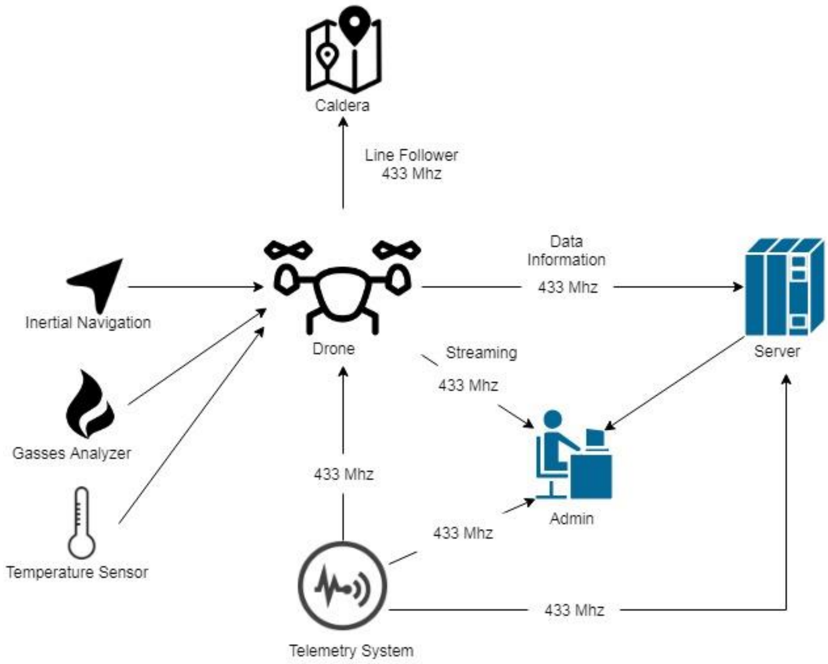

Figure 3. EWS Infrastructure Layer of mitigation in geotourism zone.

The discussion about the implementation of the mitigation process in the geotourism zone via drones discussed in this paper will be an alternative of development of EWS geotourism architecture with the zone characteristics with GPS signal limits and is part of the development of disaster management science as an alternative solution. The natural conditions of some traditional geotourism destinations are steep, rocky and hard to be reached at the potential sources of toxic gas. Indonesia and several developing countries have adopted a popular monitoring and warning approach that still relies on a local approach of heritages visually by looking at dead fowls on the ground or manually installing toxic gas concentration gauges at geotourism zones. This mmanual handling is dangerous because it risks to the safety. Another technology often used is installing CCTV in the areas where potentially affected by toxic gases. Installing CCTV has a weakness because it can only see the gas visually. When it has been at the high concentration, the gas will emit a color that is highlighted by CCTV. Referring to the aspects of geotourism monitoring activities in some other developed countries with geotourism landscape challenges that is difficult to reach is by installing toxic H2S, CO and SO2 using robotic technology approach and Unmanned Aerial Vehicle (UAV).

Potential applications of UAV Vehicles are useful for the emergency response monitoring teams to access unreachable areas, take timely steps by learning from information which is taken in the destination zone, making informed decisions related to the effective emergency response (Arain & Moeini, 2016). Mitigation technology approaches in geotourism areas generally emphasize using traditional technologies, where manual measurements by embedding sensors at certain points are often constrained by limited internet access in geotourism areas (Richter et al., 2016; Wikantika, 2018). On the other hand, the toxic gas released from the crater located at the geotourism location follows the wind direction which is difficult to predict, so that the existing approaches collide with high risk of mitigation. The novelty in drone geotourism-based mitigation is injecting an algorithm that is able to map patrol routes that are able to work even in tourism area zones that have limited GPS signals. The novelty of this geotourism approach will provide security support in geotourism zones with toxic gas vulnerability characters.

CONCLUSIONS

Drone is a strategic instrument on EWS mitigation especially in geotourism zone with the GPS signal limit character, in designing architecture using Zachman Framework, it has shown various perspectives that find the requirements of business process with the design of technology development, where at the infrastructure layer will ensure the vision and mission of EWS geotourism development that will be achieved. This paper emphasized the importance of innovation in the inertial navigation to cover the requirements of coverage area from the geotourism which are not reachable by GPS signals or have the minimal GPS signals.

LIMITATIONS AND FUTURE RESEARCH RECOMMENDATIONS

Sensor planning applied to the implementation of drone tourism as a mitigation tool has many variants related to sensor sensitivity. The physical shape of the sensor will affect the modification of the drone and this may conflict with the agility of the drone against the wind which leads to the reliability of the drone. Even though the drone sensor also applies a computer vision algorithm, reading the road path as a patrol connection point between points is often constrained by dewy drone cameras or fog that appears on the slopes of mountains where tourist destinations are located. This study emphasizes drones as a mitigation strategy tool in the context of preventive disaster management. But furthermore, future research needs to broaden the scope of the mitigation theme in a repressive context, where mitigation management needs to build evacuation routes when a toxic gas disaster occurs, connect to the nearest house according to the capacity of potential victims when a disaster occurs, and distribute aid according to the mapping need.

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REFERENCES

Apvrille, L., Tanzi, T., & Dugelay, J.-L. (2014). Autonomous drones for assisting rescue services within the context of natural disasters. *2014 XXXIth URSI General Assembly and Scientific Symposium (URSI GASS)*, 1–4. https://doi.org/10.1109/URSIGASS.2014.6929384

Arain, F., & Moeini, S. (2016). Leveraging on unmanned aerial vehicle (UAV) for effective emergency response and disaster management. *Proceedings of the Project Management Symposium at U of MD College Park Maryland*.

Dodds, R. (2007). Sustainable tourism and policy implementation: Lessons from the case of Calvia, Spain. *Current Issues in Tourism*, *10*(4), 296–322.

Erdelj, M., Król, M., & Natalizio, E. (2017). Wireless sensor networks and multi-UAV systems for natural disaster management. *Computer Networks*, *124*, 72–86.

Fassoulas, C., Nikolakakis, E., & Staridas, S. (2022). Digital tools to serve geotourism and sustainable development at Psiloritis UNESCO Global Geopark in COVID times and beyond. *Geosciences*, *12*(2), 78.

Gerber, A., le Roux, P., Kearney, C., & van der Merwe, A. (2020). *The Zachman Framework for Enterprise Architecture: An Explanatory IS Theory BT - Responsible Design, Implementation and Use of Information and Communication Technology* (M. Hattingh, M. Matthee, H. Smuts, I. Pappas, Y. K. Dwivedi, & M. Mäntymäki (eds.); pp. 383–396). Springer International Publishing.

Griffin, G. F. (2014). The use of unmanned aerial vehicles for disaster management. *Geomatica*, *68*(4), 265–281.

Hashim, K. H. b., & Jusof, M. J. b. (2010). Spherical High Dynamic Range Virtual Reality for virtual tourism: Kellie's castle, Malaysia. *2010 16th International Conference on Virtual Systems and Multimedia*, 297–300. https://doi.org/10.1109/VSMM.2010.5665945

Heggie, T. W. (2009). Geotourism and volcanoes: health hazards facing tourists at volcanic and geothermal destinations. *Travel Medicine and Infectious Disease*, *7*(5), 257–261.

Hermawan, I. (2016). Katalog Virtual Reality E-Tourism Berbasis Video 360 Sebagai Konten Digital Kreatif Bagi Media Simulasi Profil Destinasi Wisata. *Prosiding Sentrinov (Seminar Nasional Terapan Riset Inovatif); Vol 2 No 1 (2016): Prosiding Sentrinov 2016*. http://proceeding.sentrinov.org/index.php/sentrinov/article/view/140

InCorp. (2023). *Exploring the Potential of Indonesia's Tourism Industry*. In.Corp.

Knez, S., Štrbac, S., & Podbregar, I. (2022). Climate change in the Western Balkans and EU Green Deal: status, mitigation and challenges. *Energy, Sustainability and Society*, *12*(1), 1. https://doi.org/10.1186/s13705-021-00328-y

Lak, A., Hasankhan, F., & Garakani, S. A. (2020). Principles in practice: Toward a conceptual framework for resilient urban design. *Journal of Environmental Planning and Management*, *63*(12), 2194–2226.

Lan, G., Sun, J., Li, C., Ou, Z., Luo, Z., Liang, J., & Hao, Q. (2016). Development of UAV based virtual reality systems. *2016 IEEE International Conference on Multisensor Fusion and Integration for Intelligent Systems (MFI)*, 481–486. https://doi.org/10.1109/MFI.2016.7849534

Richter, N., Favalli, M., de Zeeuw-van Dalfsen, E., Fornaciai, A., da Silva Fernandes, R. M., Pérez, N. M., Levy, J., Victória, S. S., & Walter, T. R. (2016). Lava flow hazard at Fogo Volcano, Cabo Verde, before and after the 2014–2015 eruption. *Nat. Hazards Earth Syst. Sci.*, *16*(8), 1925–1951. https://doi.org/10.5194/nhess-16-1925-2016

Shekhar, S., & Valeri, M. (2023). Modelling the Effect of Spiritual Tourism Motivators on Spiritual Tourism Consumption. *Tourism: An International Interdisciplinary Journal*, *71*(3), 634–646.

Simkin, T., Siebert, L., & Sigurdsson, H. (2000). Earth's volcanoes and eruptions: An overview. *Encyclopedia of Volcanoes*, 249–262.

Tanzi, T. J., Chandra, M., Isnard, J., Camara, D., Sebastien, O., & Harivelo, F. (2016). Towards" drone-borne" disaster management: future application scenarios. *XXIII ISPRS Congress, Commission VIII (Volume III-8)*, *3*, 181–189.

Tiwari, A., & Dixit, A. (2015). Unmanned aerial vehicle and geospatial technology pushing the limits of development. *American Journal of Engineering Research*, *4*(1), 16–21.

Wikantika, K. (2018). *Environmental Baseline Assessment in Oil and Gas Activities in Indonesia Using Remote Sensing*.

Wulung, S. R. P., Putra, R. R., Permadi, R. W. A., & Maulana, M. I. (2020). Concentration-dispersal strategies to assist geotourism destination planning: A case study of Ciletuh-Palabuhanratu UNESCO Global Geopark. *Journal of Indonesian Tourism and Development Studies*, *8*(3), 156–164.

Yajnanarayana, V., Wang, Y.-P. E., Gao, S., Muruganathan, S., & Ericsson, X. L. (2018). Interference mitigation methods for unmanned aerial vehicles served by cellular networks. *2018 IEEE 5G World Forum (5GWF)*, 118–122.

Yeh, S.-S. (2021). Tourism recovery strategy against COVID-19 pandemic. *Tourism Recreation Research*, *46*(2), 188–194. https://doi.org/10.1080/02508281.2020.1805933

Zachman, J. A. (2003). The zachman framework for enterprise architecture. *Primer for Enterprise Engineering and Manufacturing.[Si]: Zachman International*.

Zhan, Z., Ali, L., Sarwat, S., Godil, D. I., Dinca, G., & Anser, M. K. (2021). A step towards environmental mitigation: Do tourism, renewable energy and institutions really matter? A QARDL approach. *Science of The Total Environment*, *778*, 146209. https://doi.org/https://doi.org/10.1016/j.scitotenv.2021.146209