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APPLYING GEOGRAPHICAL INFORMATION SYSTEM (GIS) PROCESS IN SEARCH AND RESCUE (SAR) OPERATION OF HIKING INCIDENTS

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Abstract

Hiking is now one of the most popular outdoor adventure activities among Malaysian community. For more than 10 years, hiking incidents have occurred frequently among hikers, whether in mountain hiking areas, hills or in public recreational parks with relatively low hills. Incidents during hiking can occur even if various complete preparations have been made prior to the hike. Preparation in terms of database about the hiking area's condition is not available such as hiking area background, tree, forest, and slope. With the availability of database, it will support the Search and Rescue (SAR) operation that includes safety of SAR team; coordination of resources and monitoring of operation, and post-operation analysis, planning and documentation. The implementation of IR4.0, the benefits of using technologies such as GIS that serve to form a more systematic database are seen to be able to deal with incidents during hiking. The aim of the paper is to formulate hiking incidents prevention database systems with GIS application. The objective of the current paper is to clarify the issues related to SAR operation, and environmental variables that will be used to generate spatial and attributes data. The paper applies a deductive research methodology, which includes content analysis which focuses on the process of GIS formation. The development of a database using GIS is seen to be able to help in managing the hiking area and the hiker themselves to be better prepared in the event of an incident during hiking.

Keywords*: Geographical Information System Process, Database System, Hiking, Search and Rescue (SAR), Incident Prevention.*

INTRODUCTION

Hiking is one of the popular activities and has a high demand among the community (Lee et al., 2020). In Malaysia, for example, hiking activities in particular area seen to be increasingly popular because in Malaysia the terrain is ranged (Jazwiri, 2016). According to Ismail (2018), hiking has no age limit, but it depends on the endurance of the hikers and the character of the hill or mountain. Zakariya (2022), also stated hiking is an activity that do not have a limit on the level of difficulty of climbing and it depends on hikers' preference. Although the level of difficulty of the hiking varies according to the location and the level of hiker's fitness, the incident can occur at any time (Arrive Alive, n.d). There are many websites, blogs and books that share experience, guides, tips, and tricks that need to be considered during or before hiking. With a variety of information shared by professional hikers, however, there are still many cases of incidents while hiking is reported.

The meaning of hiking incident refers to the occurrence of undesirable events such as dangerous terrain, bad weather, confusing routes or track, environment, fallen trees, missing people, straying and sudden death (Jazwiri, 2016). Referring to the archive of newspaper clippings and news such as Kosmo, Berita Harian and Astro Awani, throughout the implementation period of the Movement Control Order (MCO) in 2021 until June 2022, there were 10 cases of incidents while hiking. Among the incidents that occurred were missing, straying, death, drowning, injured and falling. According to Jazwiri (2016), there are three (3) potential factors that cause incidents during hiking, namely environment, human and weather.

Hikers have full information on preparation before event, guidance during hiking and information regarding the location of the event but referring to the mountain guide from the Malaysian Mountain Guides Association (PMGM) and the Malaysian Mountain Search and Rescue Association, Encik Muzafar Mohamd (2022), the main issue is that all information are not gathered into a database which can specifically be used by hikers, guiders, and the management team in preparing for SAR of any incidents. In addition, the Forestry Department's Portal also does not have data regarding the hiking area including character of the hill or mountain, trees, slope, and others as reference for hikers, guiders or even public.

The use of GIS in mapping and monitoring forestry areas in Malaysia is still limited (Zawawi, 2020). GIS is one of the important elements in SAR operations. During SAR operation, SAR teams do not have time to wait for a GIS specialist to arrive since they require maps immediately. Before an incident occurs, SAR teams must have ready-to-use GIS tools (Vezina and Doherty, 2021). GIS is a powerful planning and analysis tool that can help to make sure SAR team in the right places with proper manner that will effectively locate the victim (SARGIS n.d). In Malaysia, the study and use of GIS in SAR operations is very limited. As suggested by Sr. Yusrie Abdullah (2022), sophisticated equipment and technology such as lifting victims and delivering necessities at high-level incidents using helicopters, the use of drones or using Geospatial Analysis Techniques to obtain the distance of the earthquake's effects from a point of extreme earthquake. It differs from its use abroad. According to Zawawi (2020), the use of GIS encompassing spatial applications has been widely adopted in western countries in the management of recreational areas especially those involving SAR operations such as search and rescue operations of hiking victims in California State Park (Doherty, 2021), position tracking and GIS in search and rescue operations in Norway (Hanssen, 2018) and GIS assisted problem analysis of trail erosion in Monongahela National Forest (Storck, 2011).

Industrial Revolution 4.0 (IR4.0) refers to the transformation in industry using new technologies that merge the physical, digital and biology, that affecting all fields including industry and economic activities (Economic Planning Unit, Prime Minister's Department, 2021). Through the implementation of IR4.0 enables the application of more sophisticated technologies, innovation, and the emergence of new business models in all sectors. GIS is one of the technological systems that has advantages in database storage and give a positive impact on the forestry sector (Ibharim, 2020). In addition, according to Fauzi (2015) GIS also work as a medium for database development and indirectly has the potential to present attribute data along with spatial data that shows the location of an area and then analyse the data. However, there are limited studies have been conducted regarding the use of GIS processes in handling incidents during hiking activity. With the formation of a database using GIS is seen to be able to help in managing the hiking area and the hiker themselves to be better prepared in the event of an incident during hiking.

LITERATURE REVIEW

The current trend in recreational activities is showing a shift from established routes with high-profile attractions to forested, remote and adventurous settings, which offer nature and wilderness experience. One good example of adventure activities is hiking. Hiking is

identified differently in different places, ranging from walking, bushwalking, outdoor walking to trekking and hill walking (Slabbert and Preez, 2017). Unfortunately, these settings are mostly associated with risk, in the form of injuries and illnesses which may occur to the recreationists. Heggie and Heggie (2012) stated that due to the rise in hiking participants, research literature has shown an increasing number of hiking injuries and illnesses. The study highlighted that hiking made up 10% of recreational fatalities and 48% of SAR operations in U.S. National Parks. In addition, a study by Johnson, et.al. (2007) highlighted that hiking inflicted injuries contributed to 10% of all injuries in popular destination like Yellowstone National Park, U.S.

Morgan and Dimmock (2006) asserted that nature-based and adventurous activities which earlier on may only cater for small numbers of enthusiastic participants have now attracted many more participants in risky activities. The growing interest in risky activities and adventures owe much to social change in the society as well as technical advances in adventure experiences. For example, now access to inaccessible locations are made easier by the existence of terrain vehicles and helicopters; advances in equipment and clothing which are readily available and user friendly complementing the improved access to natural locations.

The incidents related to hiking, mountaineering and forest recreation have resulted in a hike in the call for SAR operations. Li and Dong (2014) asserted in the case of mountain disaster incidents, there are several rescue features to be considered. There are as follows: i) rescue timeline, ii) the distance, iii) the terrain, and iv) the communication. These are then followed by the following basic procedures of rescue which include from receiving alarm and rescheduling to the final stage of on-site clean-up. However, when incidents happen, the evacuation options of SAR operations are often impeded by factors such as the nature of the terrain, the type of injuries, the weather, and the equipment and supplies available (Thinaraj, et.al., 2020).

Having precise, understandable, and appropriate information in a timely manner proved to be significant in times of emergency such as during the SAR operations (Hanssen, 2018). This study highlighted how GIS assists in visualising information and presenting it on a digital map for tracking, and, hence, reduces stress in the command centre or post. The use of GIS support in addressing issues such as the safety of SAR team; coordination of resources and monitoring of operation, and post-operation analysis, planning and documentation.

The main reason for any SAR mission is to find the missing casualties and bring them back to safety. In enabling this to happen, search managers must engage in efficient procedures which will not pose unwarranted risk to the rescue crews. As stated by Ferguson (2008), modern strategies may include behavioural profiling, probability theory, terrain interpretation and resource management. Geographic Information System (GIS) assists in incorporating these diverse elements into an effective tool for managing SAR. GIS combined current aerial and satellite imaginary and elevation models with digital topographical map, enhancing SAR operations, which previously relied upon outdated maps. The study highlighted the fact that in most SAR operations, the searching part often becomes the most difficult part. This may hinder the probability of success (POS) of any SAR operations.

Flushing, et.al. (2012) stated that to coordinate and manage emergency response is not an easy task, made harder by the local terrain features and environmental conditions, which may affect the success of the exploration tasks. In solving this issue, the study suggested the use of a mission support tool incorporated with GIS to help in monitoring and decision-making of rescue efforts. In this study, GIS is used to model the relationships between the environment and the performance of the rescue mission through what is called Search Efficacy Model which takes into consideration the environment's local features. The study also highlighted the benefits of engaging position tracking and GIS in SAR operations as being: i) ensuring the

safety of SAR personnel, ii) effective and efficient coordination of resources, and iii) availability of information for post-operation analysis and documentation.

A study by Nefros, et.al. (2018) showed that using GIS in producing prioritization maps (heatmaps) prior to a natural disaster, assist in effective and quick decision-making process in SAR operations, thus, reducing the number of casualties as well as, ensuring the quick recovery of the whole area to normality and stability.

Snoeren, et.al., (2007) stated that spatial data infrastructure (SDI) assists and coordinates the switching of static and dynamic spatial data between the multidisciplinary rescue teams, consisting of fire brigades, police, paramedics, and the government. SDI core components consist of data, people, policy, and technical components, namely, access networks and technical standards. The technical components facilitate relationships between people and data.

The use of Geo-ICT in emergency responses addressed several interesting aspects. Zlatanova and Fabbri (2009) asserted that Geo-ICT stirred information awareness on the inadequacy of data on existing resources, types of data, availability, and accessibility of data during large disasters. Since emergency management involves multidisciplinary activity, exchange of information should be made possible between the different agencies or teams. There is a need to have relevant icons and symbols which dismiss intuitive interfaces during emergency situations, thus, reducing the possibilities of 'expensive' errors which involve life or death situations.

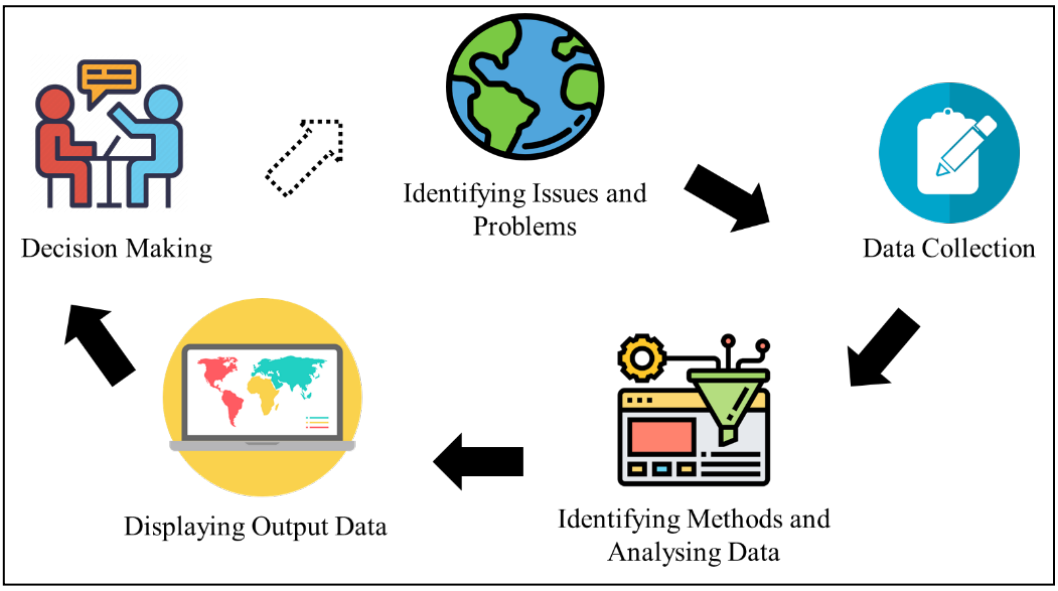
Cova (1999) asserted three main roles of GIS in emergency management, as being: i) mitigation in relation to analytical modelling, ii) preparedness and response in which GIS is used in formulating and executing emergency response plans, and iii) recovery in which GIS is serving as spatial inventory systems in coordination recovery actions. The ability of GIS to accomplish not just regular search, but also, to use the mechanisms of generalization and detailed analysis of the information obtained in making decisions, through visualization of geographical data, makes GIS more outstanding from other systems (Yemelyanenko, et.al., 2018). There are five (5) methods of GIS process, namely identifying issues and problems, data collection, identifying methods and analysing data, displaying output data and decision making. Identifying issues and problems are very important in research. In creating a GIS database, data collection is very important before the process of data entry into GIS software. These data can be obtained from primary data and secondary data from the study area or departments and agencies concerned (Hua, 2015). The data can be collected in the form of spatial or attribute data. The next process is identifying methods and analysing data that use vector or raster data format (Hua (2015). While displaying process of data output, vector and raster data that formed earlier will produce plans, tables, statistics, or text analysis based on methods that determined according to the field or scope of the study. Processes such as the query, analysis, documentation and producing of the thematic maps were performed by means of GIS software used (Turk et al., 2014). The last process is decision making that who will make the decision based on the findings of the study depends on the stakeholders in the study. The following diagram shows the workflow process of GIS. This process will be repeated if the issues and problems identified cannot find a solution.

METHODOLOGY

This paper is using content analysis which to examine text in the article and journal as main data to formulate the environmental variables of hiking incidents prevention database systems using GIS. There are five (5) process of database formulation, spatial analysis and decision making which refers to studies that have been conducted previously that can be used in SAR operations. The process includes:

i. *Identifying issues and problems: the incidents factors that will happened at the event*
ii. *Data collection: the variables (based on factor)*
iii. *Identifying methods and analysing data: formulation of spatial and attribute data*
iv. *Displaying output data: software that will used*
v. *Decision making: parties were using the database and the action to be taken.*

Figure 1
Workflow process of GIS



RESULTS AND DISCUSSION

As mentioned before, the use of GIS in SAR operations has been used especially on developed countries. Doherty (2021) states that GIS can help in SAR operations by getting information and decisions. One example of GIS that used by the countries is SARGIS. SARGIS is a group for National Park rangers, sheriffs, firefighters, mountain rescue volunteers, and other emergency service people to discuss and help others use and implement GIS technology in SAR, emergency, and day to day operations. Central to the group's primary objectives is to make GIS techniques and technologies more accessible to non-specialists. SARGIS has continued to investigate techniques and skills that can result in a more streamlined workflow and efficient situational awareness when using GIS (SARGIS n.d). Unfortunately, there are limited studies that mention on formulate hiking incidents prevention database systems with GIS application. To formulate the database system, the use of five (5) GIS processes can be implemented before the hiker, guider or the management team of the climbing area decides to perform hiking activities.

i. *Identifying Issues and Problems*
In the first process, hikers, guiders, and the management team need to identify incidents happened at the event. There are several categories of incidents while hiking (Jazwiri, 2016) but this study only focusses on incidents that caused from landform and vegetation factors. This is because based on the search results in the archives of newspaper clippings and news of mountain hiking incidents in 2021 and 2022 mostly due to landform and vegetation factors. Incidents caused by terrain factors include uneven hiking areas, rocky terrain, slippery, sharp, and mossy relief, steep tracks, water head paths, landslides, and rooted tracks. While plant factors are

such as areas of rotten trees that are at risk of falling and poisonous trees that pose a threat to hikers.

ii. *Data Collection*

The process of identifying the incident has been done and then the process of collecting data based on the factors of the incident. The data collection process can be obtained from two (2) sources, namely primary and secondary data. The data collection process is very important to deal with incidents during hiking. For primary data collection, hikers and guiders will collect and share data on areas and hiking routes (tracks) where incidents have occurred, risk and potential incidents such as terrain factors and plant factors. Hikers and guiders are important resources because they are individuals who have gone through the route (track).

While for secondary data collection, data that can be collected are including details of incident, specific areas and potential and risk routes based on landform and plant factors can be obtained from the Peninsular Forestry Department (JPSM), Department of Minerals and Geosciences Malaysia (JMG), Fire and Rescue Department and newspapers. The data collected are in the form of spatial data and attribute data.

iii. *Identifying Methods and Analysing Data*

The next process is identifying methods and analysing data. The data that has been collected earlier will be identified and transformed into spatial and attribute data. Spatial data is including the location plan and gradient plan of the hiking area where the incident occurred or the Area where the incident is potentially occurring. Apart from that, the need to identify exact areas and location of trees that pose a threat is also important. Meanwhile, data attribute is from inventory, survey, interview or checklist.

The methods and analysis produced should answer the question of how to deal with incidents while hiking? The question needs to consider the incident factors that have been identified during the first process. The following table shows the methods and analysis developed to answer the research questions.

Table 1

The methods and analysis developed to answer the research questions.

Research Question	Method and Analysis
Where is the location and potential of landslides?	Plan of potential area for landslides Slope data
Where areas are at risk of soil erosion?	Plan of potential area for soil erosion Soil erosion data
Where is the risky route?	Plan of risky routes Data on the types of risks and incidents that have occurred on the route.
Where is the location of the trees that pose a threat?	Vegetation and trees plan Tree inventory

iv. *Displaying Output Data*

The GIS system has several software that can be used in generating and displaying data such as ArcGIS, MapInfo, Global mapper, AutoCAD Map, etc. (Ali, 2020). By using a GIS system, the data that will be displayed is in the form of spatial data that displays the visualization of data resulting from data analysis. Spatial data is divided into two (2) types of data, namely raster and vector data. To identify the

appropriate type of spatial data to be displayed, researchers need to ensure that spatial data (plans that show the location or space) and data attributes (tables on the location or space) can be translated and displayed in the GIS system. For this study, there are several plans required and each plan has different data attributes (inventory data) based on the methods and analysis that have been conducted. The following are examples or suggestions of spatial data and attributes data that will be displayed when the analysis results are generated using a GIS system.

Table 1
The suggested spatial data and attributes data that will be generated using a GIS system.

Spatial Data (Pelan)	Attribute Data (Inventory)
Plan of potential area for landslides	Slope data
Plan of potential area for soil erosion	Soil erosion data
Plan of risky routes	Data on the types of risks and incidents that have occurred on the route.
Vegetation and trees plan	Tree inventory

Spatial display of data (plan) and attribute data (inventory data) must be produced by the management of the hiking area. With the plan and inventory data (database) can help the management to identify areas at risk of incidents in that area and then the data can be shared with hikers or guiders.

v. Making Decisions

At this stage, decisions are made based on the analysis that has been generated and displayed using the GIS system. In this study, the decision -making parties are the hikers, guiders, and the management team. Once the management team produces a database and analyses the areas at risk of incidents during the hike, they will decide whether to give permission to the hikers to continue the hiking activity or not. Although permission to hike is given, but with the location plan database and inventory data will help the management team in giving out notice and reminder to hikers to be extra careful when passing through areas that have a risk of incidents that may be due to terrain or vegetation factors in the area. If there is also an incident during that activity even though the information has been given to the hikers, with this database the management team can also share the information to the SAR team to carry out rescue work for the hikers in the risk area.

CONCLUSION

Using GIS process methods in dealing with mountain hiking incidents can help the management of hiking areas gather important data, identify risk areas and areas where incidents occur, analyse the areas, and decide whether to give permission for hikers and guiders to continue their activities or not. In addition, the database produced should be open access so that hikers and the public can get accurate information about the current situation of the climbing area. In addition, the database is seen to facilitate SAR operation in the event of an incident where the fire brigade or SOS can identify areas at risk and can make initial preparations for all probabilities of incidents in the area. In addition, one conclusion that can be identified is that the GIS process has indirectly formed a new framework in risk management methods that focus on incident prevention for outdoor recreational activities such as climbing. However, the main challenges in implementing this GIS system process are the cost of

expensive GIS software, very limited expertise in the field of GIS and the implementation of the system is not comprehensive in public and private agencies.

Future research should focus on implementation of the GIS process in risk management that focusing on incident prevention while hiking that not only focus just on hiking activities but also can be used for other outdoor activities.

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