GIS BASED ANALYSIS FOR EMERGENCY RELIEF AND RESCUE AND DISASTER MITIGATION

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ABSTRACT

This research was aimed to contribute GIS capabilities to military emergency relief and rescue and disaster mitigation that require the detailed analysis of an area and environment prior to performing a mission. At an ultimate goal of maintaining faulty mechanic equipment that consists of backhoes and tailgate trucks for the Mobile Development Unit 31 of the Armed Forces Development Command to prevent and solve public and disasters problems in Pua district of Nan province, the objective was to use GIS for a route selection mission of Mobile Development Unit 31 in the mission of disaster prevention and solution. A sample road network database covering Pua district was prepared and tested for the simulation of an optimal route selection based on an actual landslide incident in the district reported by the news media. The Mobile Development Unit 31 was set as the starting point of the routing while the landslide location was set as the target point. Field survey along the selected route was presented as proof of concept. More factors dictating route selection were recommended for a more accurate route selection.

1. INTRODUCTION

The Armed Forces Development Command is a military agency under the Ministry of Defense. It is an ally member of the Department of Disaster Prevention and Mitigation under the Ministry of Interior. It has an important duty in preventing and solving public problems and disasters. Its direct report units are scattered throughout Thailand to reach the problems of the people in every corner of the country. Therefore, they are the military unit that is faced with a wide variety of public services and disasters according to the area of responsibility. Units in the northern part are located in mountainous region with high mountain terrain, they often encounter landslides. Most of the equipment under responsibility is mechanical such as backhoes or tailgate trucks, etc. Most of them have been in use for more than 10 years and therefore have deteriorated over time. Mobile Development Units have also attempted to maintain their conditions to help the people. Therefore, if principles and technology can be applied to enable the units to continue to operate the faulty equipment, the units will perform the disaster prevention and mitigation mission in the best interest of the people in the area.

This research project is a collaboration between Defence Technology Institute and Mobile Development Unit 31 or MDU31 of Armed Forces Development Command. The goal is to use Geographic Information Systems (GIS) to transform geospatial data into a tool for emergency relief and rescue and disaster mitigation. The database will be used for disaster management which requires the detailed analysis of the area and environment prior to performing the mission. This will contribute to the maintenance of MDU31's faulty mechanic equipment in order for the MDU31 to prevent and solve public and disasters problems in the study area of Pua district in Nan province. The objective is to use GIS to support the MDU31 in the mission of disaster prevention and solution in response to landslides in the study area by optimal route selection for the transport of the faulty mechanical equipment. The technology to maintain the state of mechanic equipment will be introduced to the units and the principles and processes will be tested in the actual problem area.

2. GIS IN DISASTER MANAGEMENT

Coppock (1995) conducted a brief survey of the diversity of such hazards and made an attempt to review what had been written in the past, a task made difficult by the wide range of interests involved. The review showed that, within the GIS field proper, relatively little had been published and that, within the disciplines studying natural hazards, few papers described operational systems that were applied routinely, four examples of which were summarized. van Westen (2000) discussed that the collection and management of spatial data from remote sensing and GIS were regarded proper to handle a large amount of data and had demonstrated their usefulness in disaster prevention, preparedness and relief. The objectivity and reproducibility of assessment were considerably improved by sequential imagery interpretation with quantitative description of the factors and well defined analytical procedures and decision rules, which were applied to come to the hazard assessment. In response to the previous discussion, Johnson (2000) claimed that GIS was the foundation for emergency management. As soon as potential emergency situations were identified, mitigation needs could be determined and prioritized. Utilizing existing databases linked to geographic features in GIS made quick displays of values at risk possible. Thus, the closest and quickest response units could be selected, routed, and dispatched to an emergency once the location was known. The review of Tomaszewski et al. (2015) provided interdisciplinary literature from a variety of spatially-oriented disaster management fields and demonstrated progress in various aspects of GIS for disaster response. They further concluded that a GIS for disaster response research agenda and provided a list of resources for researchers new to GIS and spatial perspectives for disaster management research.

3. GIS BASED DISASTER MITIGATION CONCEPT

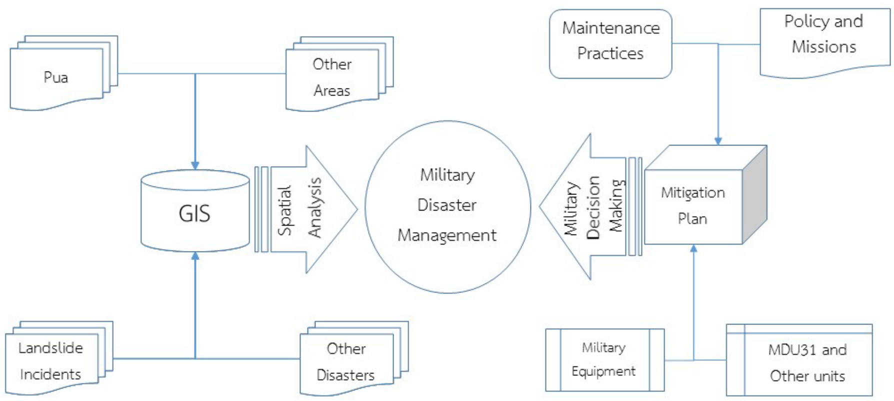

Figure 1. Concept of GIS based analysis for disaster mitigation.

The ngagement of GIS and disaster mitigation is proposed for military disaster management as shown on Figure 1. All geo-referenced data is handled in GIS with emphasis on landslide data and previous records of the incidents. This GIS systematic approach can be applied to other areas with frequently incurred disasters. The spatial analysis capability of GIS plays a major on the GIS side of the management while a military decision making alternatives is the output result of disaster mitigation component. Policy and missions will drive the mitigation plan while regions under responsibility contributes how decision is made and equipment allocated.

4. RESEARCH METHODOLOGY

The research methodology proposed in this project is illustrated in Figure 2. Four stages are followed to implement GIS based disaster mitigation that returns optimal routes to dispatch military equipment from MDU31 to landslide sites.

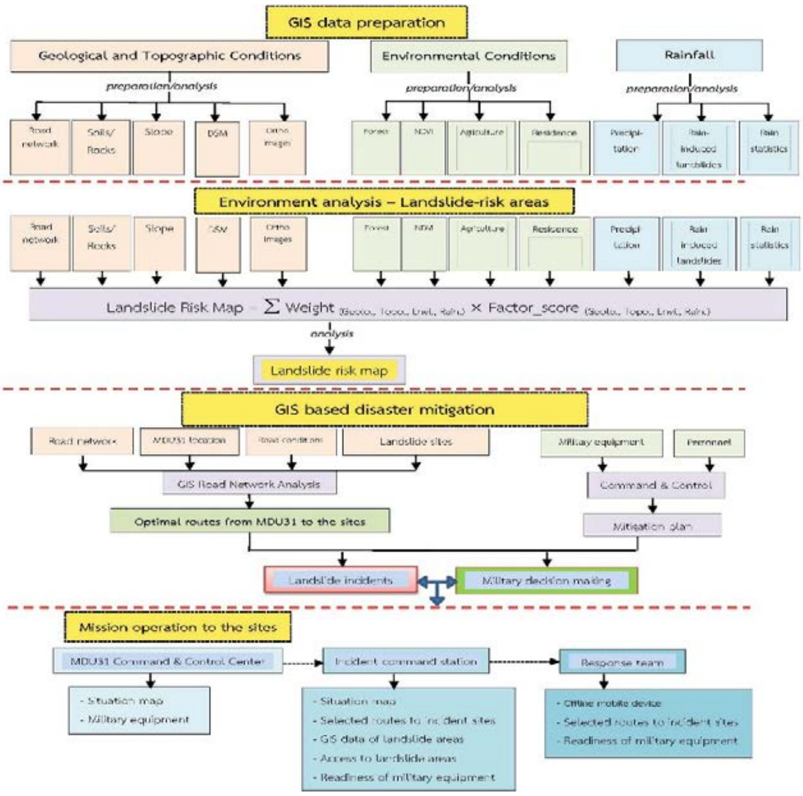

Figure 2. Use of GIS based disaster mitigation to access landslide sites.

4.1 GIS data preparation

GIS data preparation was to ensure essential geo-spatial layers are ready for further analysis processes. Four types of data were central to the spatial analysis for a landslide risk map. Geological and topological conditions were integral in nature while environmental ones needed further GIS data manipulation before the analysis. Rainfalls were largely regarded as dynamic especially precipitation and rain-induced landslides. Rain statistics were influential factors to the magnitude of rainfall to landslide incidents.

4.2 Environment analysis for landslide-risk areas

The analysis of environments for landslide – risk areas to produce a landslide – risk map took the summation of weighted 4 factors. GIS data layers describing geological and topological conditions each carry a 30% combined weight percentage while those containing environmental and rain conditions were each carry a 20%combined weight percentage. The result map revealed those patches prone to landslides. Though a road layer was weighted in the weighting process, it next provided accessibility to the mapped landslide sites.

4.3 Mitigation command and control

Prior to implementing this stage, a road network needed to complete connecting edges and nodes so that the network analysis could be reiterated for starting and end points. Road attributes describing surface, lane number, width intersections etc. were conditions that later determined whether military vehicles and equipment on which they could be transported from the analyzed starting to end points. Records of vehicle maintenance and regular checks were data for command and control of the vehicles for the mission (Figure 3 left) in which the traffic was completely blocked by the landslide (Figure 3 right).

Figure 3. Maintenance practices (left) before mission in the site (right).

4.4 Onsite mission operation

This three cascaded operation of figure 2 includes command and control from the MDU31 center, holding a big picture situation map and complete military equipment database, incident station commanding the mission upon the selected routes to the sites with an offline copy of dataset from the center, and the team responding to the incident with mobile devices to track the selected routes and handling the military equipment at the landslide sites.

5. CASE STUDY

In order to achieve the objective of this research article, case studies of a landslide incident retrieved from online media was showcased, road network data was analyzed for the route selection mission of MDU31 in disaster prevention and solution. The following describes the case study extracted from the lowest portion of Figure 2 in response to the objective.

5.1 Landslide-prone study area

As part of the MDU31 landslide disaster management project, Pradabmook and Laosuwan (2021) reported the research output that Nan Province had areas prone to soil erosion of about 3,685.206 km^2 or equal to 57.73% due to the topology characterized by forest and mountain for almost 75 %. Where agricultural activities were found to be planted on the mountain with steepness of more than 5% in a total area of 6,975.325 km^2 or equal to 60.80%.

5.2 GIS road network

Yi et al (2012) calculated the shortest evacuation routes between affected points and shelters or Origin - Destination ranking model where considerable roads and land features and other environmental factors when the closest facilities and routes were selected, selection criteria and approach methods could be suggested for future events. Likewise, in this research the network of roads was formed by the connectivity of arc segments constituting an individual road. Then, road network database consisted of Edge to connect components such as sections or intersections, Junction to connect arcs, and Turn to define directions. Connectivity analysis came in two types i.e. group connectivity and road connectivity within the same group. The latter connectivity connected roads of the same group in two types namely Endpoint connectivity for simulating object crossover and Vertex connectivity for dividing a line segment into sub-segments. A snapshot of Pua road network dataset is shown on Figure 4.

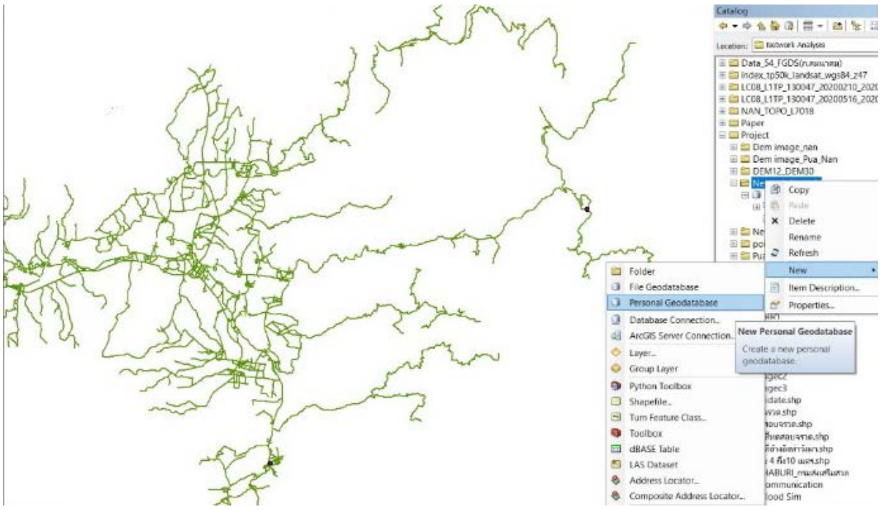

Figure 4. Pua district road network dataset.

5.3 Actual landslide incident

According to Siamrath online (at https://siamrath.co.th/n/97454#) on 17 August 2019 at 16:34 Nan province local time, there were heavy rains day and night and 60 villages of Nan province were at risk of flooding and landslide blocking the road linking Pua district to Bo Kluea district. Along the road from Pua to Bo Kluea at the front gate to Doi Phu Kha National Park, the road was blocked by sliding mountain.

6. ROUTE SELECTION AND VALIDATION

6.1 Route selection

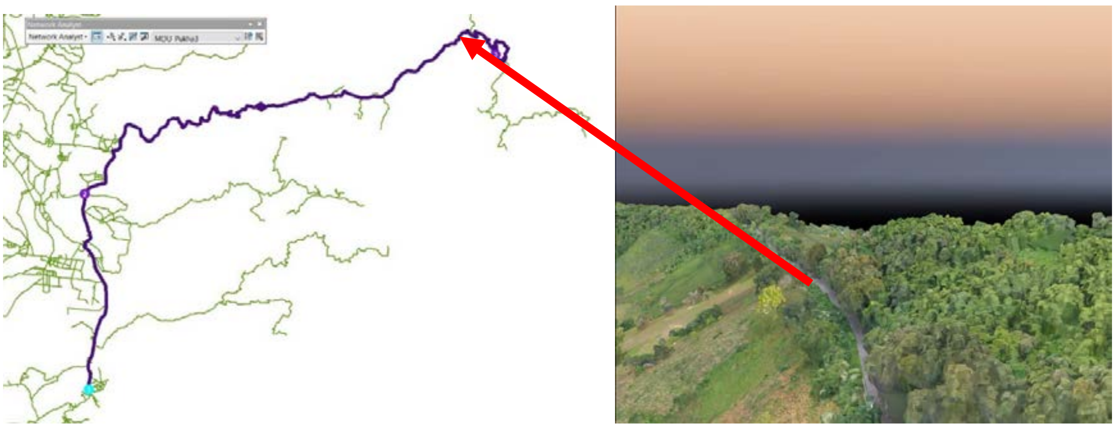

Figure 5. Selected route and simulation for validation.

The road network analysis for route selection returned the route result as shown on Figure 5 left. The starting point of the route began at MDU31 (see the lower left), traversed along National Highway No. 1080, National Highway No. 1258 and Nan Rural road No. 2047 to end at the landslide incident area as reported online by the media. The total distance was measured at 30.3927 km.

6.2 Selected route validation

Figure 5 right was a snapshot extracted from the flythrough simulation of the selected route generated from the 5 cm. resolution mosaic of orthoimagery being draped on the DSM of the same resolution. An arrow is to provide a visual link from the snapshot to the selected route resulted from the road network analysis. Road surface was assumed to be concrete with the sufficient road width to accommodate military vehicle to transport to the site. Road characteristics input to GIS attributes were on the way in the project. Site ground survey could have best validated the selection but the COVID-19 pandemic made it impossible.

7. RESULT AND DISCUSSION

The route of 30.3927 km. distance was selected from the dataset to demonstrate the integrated GIS and military decision making for the MDU31 to access the actual landslide site. The route was simulated to illustrate the road conditions sufficient for the transport of MDU31 vehicles and equipment to the blocked road of the landslide site. However, the complete use of GIS based analysis for emergency relief and rescue and disaster management for optimal access to landslide sites was subject to further studies of DTI ongoing project for MDU31. Road conditions were recommended for the more accurate route selection. More surveys to update the road dataset wwere under development as well as integral military decision making of MDU31 for the disaster management. Other landslide sites as reported by the press will be input to the analysis for solutions to test and evaluation of the dataset for road network analysis.

8. REFERENCES

Coppock, J.T., 1995. GIS and Natural Hazards: An overview from a Gis Perspective. In: Carrara A., Guzzetti F. (eds) Geographical Information Systems in Assessing Natural Hazards. Advances in Natural and Technological Hazards Research, vol 5. Springer, Dordrecht. https://doi.org/10.1007/978-94-015-8404-3_2.

Johnson, R., 2000. GIS Technology for Disasters and Emergency Management. An ESRI White Paper - May 2000. Redlands, USA. 12p.

Kumsap, C., 2018. Concept of Mobile C4ISR System for Disaster Relief. *National Defense Studies Institute Journal*, January – April 2018, Vol 9 No.1, pp. 7 – 19.

Kumsap, C., Witheetrirong, Y., and Pratoomma, P., 2016. DTI's modeling and simulation initiative project to strive for the HADR mission of Thailand's ministry of defence. *Proceedings of the 6th International Defence and Homeland Security Simulation Workshop*, September 26-28 2016, Cyprus, 44-51.

Pradabmook, P. and Laosuwan, T. 2021. The Integration of Geo-informatics Technology with Universal Soil Loss Equation to Analyze Areas Prone to Soil Erosion in Nan Province. *ARPN Journal of Engineering and Applied Sciences*, Vol. 16 No. 8, 823-830.

Robert, O. P., Kumsap, C. and Janpengpen, A., 2018. Simulation of counter drugs operations based on geospatial technology for use in a military training simulator. *International Journal of Simulation and Process Modelling*, Nol.13 No.4, pp. 402 - 415.

Tomaszewski, B., Judex, M.,Szarzynski, J., Radestock, C. and Wirkus, L., 2015. Geographic Information Systems for Disaster Response: A Review. Journal of Homeland Security and Emergency Management. June 2015. DOI: 10.1515/jhsem-2014-0082.

van Westen, C.J., 2000. Remote Sensing for Natural Disaster Management. International Archives of Photogrammetry and Remote Sensing. Vol. XXXIII, Part B7. pp. 1609 - 1617.

Yi, C., Park, R. S., Murao, O., and Okamoto, E., 2012. Emergency management: Building an O-D ranking model using GIS network analysis. *Journal of Disaster Research*, Vol.7 No.6, 793-802.