Urban Hazards Management: A Case Study of Langat River Basin, Peninsular Malaysia

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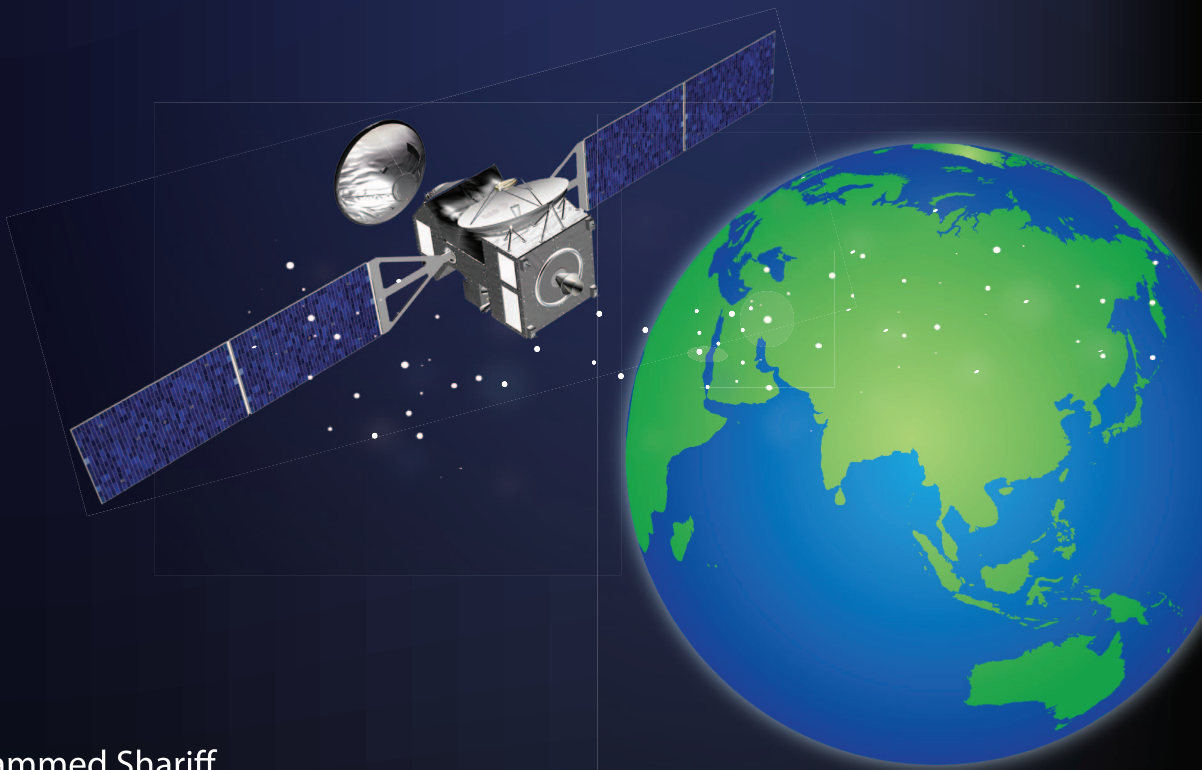

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Urban Hazards Management: A Case Study of Langat River Basin, Peninsular Malaysia

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***Abstract*—The escalating impact of the disasters that occur in urban areas requires significant attention and planning in order to minimize vulnerability and disaster risk. However, efforts made to minimize disaster risk involves various disciplines, and can be viewed from numerous perspectives that need to be addressed in an integrated manner, and then effectively formulated to provide long term benefit. With the great potential of the GIS, incorporating both the physical and social aspects associated with disasters to reduce vulnerability will form a comprehensive disaster management operation. Therefore, this study aims to translate various hazardous information that is physical and socio-economic in nature into a comparable layer within a GIS platform to assess the study area in an integrated manner. We have conducted a study in the Upper-Langat river basin, Peninsular Malaysia, which has been experiencing numerous disasters including floods and landslides. A hazard assessment was conducted to: systemize the intricacy of the geo-data, identify the predisposing and triggering factors associated with natural hazards, and integrate them spatially to derive multi-hazards data for effective hazard management. The findings revealed that spatially explicit data and maps at the relevant scale based on the surface and subsurface information, integrated with socio-economic vulnerabilities, provide better results that might be beneficial for multi-disaster risk reduction operations. It is also evident that the GIS has the sufficient capacity to translate various physical, compositional, and socio-economic aspects to the comparable outputs. Such spatially explicit products will expedite the decision making process for disaster risk reduction operations.**

Keywords- urban disaster; landslide; flood; GIS; integrated disaster risk map; decision making process

I. INTRODUCTION

Living in cities is attractive to most people as it offers various opportunities for the urban population to improve their quality of life. The rapid growth of urban areas are speeding up the urbanization rate thus establishing competitive advantages in terms of higher wages, education, healthcare, and social and cultural attractions, resulting in a better quality of life [1]. Urbanization modifies the landscapes and land patterns to accommodate the needs and demands of the growing population resulting in various environmental problems ranging from a local to a global scale. The expansion of the urban areas to fulfill its inhabitants need have led to humans concentrating within the areas that are exposed to hazards. The intensity of extreme events such as natural hazards including floods, flash floods, landslides, typhoons, droughts and many others, have long been a critical issue in urban management as it poses a threat to the urban population. The presence of humans, infrastructure and other forms of vulnerabilities have exacerbated the natural hazards thus leading to disasters [2]-[4].

The escalating impact of disasters in urban areas requires significant attention and planning to develop and manage disaster risks in order to minimize the negative impacts [3]. It is recognized that population growth and asset accumulation are likely to increase the exposure to disaster risks; thus, reducing vulnerability will continue to be an important component of managing or reducing this risk [3]. In addressing this issue more credibly, a comprehensive disaster management initiative that incorporates both physical and socio-economic aspects of disasters is the key to reducing vulnerability. Natural hazard analysis involves mapping and identifying future hazardous zones through the analysis of the predisposing criteria and triggering factors [5]. To date, the study of identification of risk zones and the delineation of potential hazard-prone areas [5]-[9] has shown a remarkable progress through the literatures. Numerous findings obtained from these researches have facilitated and well-served the various planning strategies including disaster risk reduction and development.

In view of the emerging challenges of urbanization and population growth, innovative land use planning and management of urban development to reduce vulnerability and to minimize risks are crucial. Most researches that have been conducted particularly focused on specific site-based hazards; however, they failed to provide sufficient and meaningful information for the decision-makers to make informed decisions. Integrated disaster risk mapping has emerges as to visualize the real time issues in a spatially explicit outputs that facilitate proper need-based decision-making. In order to address a holistic disaster management, this research has considered multiple disasters in the study area particularly over the past 15 years; however the co-production of knowledge is still limited and implementation gaps between research and practice persist [10]. In general, integrated disaster research appears in literatures with a diverse array of scopes include scales (local to global), stakeholders (experts, officials, and professionals), knowledge (scientific and local), disciplines (physical, social, and human sciences), methodological approaches, areas of application or implementation (planning, sustainable development, and policy) and real world experiences [10].

Geo-information technologies provide a powerful tool to strengthen the effectiveness of integrated disaster risk mapping. Systematic use of this technology has an immense potential in facilitating land use planning and management or urban development to reduce vulnerability and to minimize the disaster risk. Therefore, the purpose of this study is to translate various hazardous information that is physical and socio-economic in nature into a selective collection of comparable layers in a Geographic Information System (GIS) platform to assess the study area in an integrated manner. This paper will also include a preliminary case study in order to show a clearer picture of how this technology can be described as a supporting tool in decision-making and to promote it in assisting integrated disaster risk reduction. The following section will further discuss on the aspects of Geo-Information Technologies for hazard management and how they used in the preliminary case study, details and methodology, preliminary results, scope of future research, and finally some conclusions are drawn.

II. Geo-Information Technologies For Integrated Disaster Risk Mapping

Urban planners, decision-makers and stakeholders are the group of people that play critical roles in the decision making processes regarding various aspects of risks, vulnerabilities, and impacts of disasters. They must be better equipped with simplified but informative and understandable information to enhance their competence in the decision-making process in managing hazards. Geo-Information technology comprising of Geographic Information System (GIS), Remote Sensing, Global Positioning Systems (GPS), Digital Photogrammetry, and Surveying and Mapping [11], [12]. These technologies have shown rapid development over the years and have been used in diverse array of fields including disaster management and research. Among different technologies used, GIS is recognized as a basic and useful tool in managing disasters [13], [14]. This technology has been applied in several important phases in the disaster management cycle, which include prevention, mitigation, preparedness, response, and recovery stages. GIS is often found at its potential for mapping spatial data processing and visualizing meaningful information. Further explanation about the usability and potentials of GIS is discussed in [11], [13], [15], and many others.

In the past, research attention for managing disasters was largely focused only on individual hazards that covers the hazard itself, its frequency, and magnitude rather considering social aspects. Social aspects are often missing in most disaster studies mainly because of the complexity and difficulties in measuring their relevance and interrelations with disasters [16]. Presently, it is recognized that understanding and focusing on the physical aspects only are insufficient for mitigating disasters and reducing their increasing losses and casualties [17]. This is because the underlying social aspects that include growing economic losses, high numbers of casualties and the disruption of livelihoods are also the key determinants of disaster risk [15]-[18].

This indicates that effort in reducing disaster risk involves many disciplines and can be seen from numerous perspectives. All of these need to be approached in an integrated fashion and formulated in such a way for a long term benefit [19]. In the perspective of this study, GIS has made it easy to incorporate the social aspect, linking it with physical parameters and integrating them on a spatially contextualized basis. Consequently, the integrated disaster risk map will not only delineate the risky zones, but it will also identify the vulnerable population that lives within that area. This will provide an effective and holistic decision-making input that takes into account both aspects that contribute to better management of disasters in comparison with the present.

III. Methodology

The study has been conducted in the Langat River Basin, Selangor, Peninsular Malaysia. The Langat River Basin is the most urbanized river basin in Malaysia. Topographically the whole basin can be categorized into three distinct categories; mountainous, hilly, and low land areas [20], [21]. The mountainous area is located in the northeast part of the basin whereas the hilly areas are dispersed between the mountains and the plains and the low lands are mostly located in the southern part of the basin [20]. However, the investigated area only covers the upper-part of the Langat River Basin, which comprises of several major townships including Bangi, Kajang, Cheras, and Hulu Langat as shown in Figure 1. Those areas are in the threat of natural and urban hazards such as flash flood, flood, landslide and accelerated erosion. As to explore the potential of the integrated disaster map to serve as decision support tool to reduce risk and vulnerability, this study will focus more on landslides and flood.

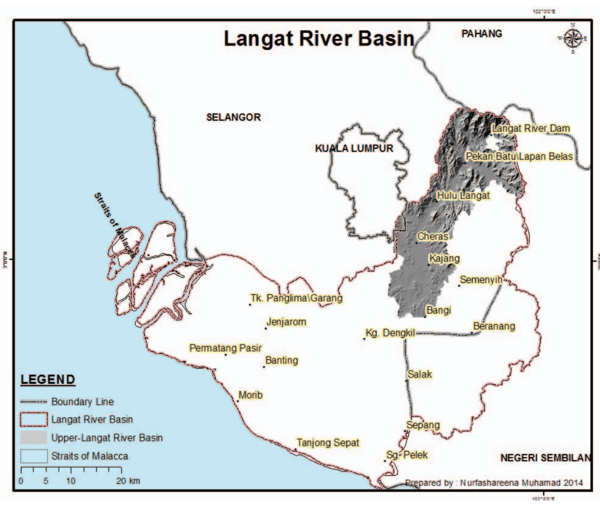

Figure 1. Upper-Langat River Basin, situated in the state of Selangor, Peninsular Malaysia

The current study requires a relatively large volume of multidisciplinary and technical data derived from various sources. These data can be categorized into several categories; a) inventory, b) predisposing criteria, c) triggering factors, d) element at risk. GIS is used to collate and analyse several locations of landslides as well as floods occurrences and these are later plotted onto a map for inventory purposes. Relevant information obtained from the inventory is crucial to observe the distribution and pattern of the occurrences of the hazards [22]. The selection of the predisposing criteria is based on the content analysis of numerous previous literatures, depending on the type of natural hazards, its topographical condition, and the availability of the data. Predisposing criteria are usually factors that may influence and contribute to the occurrences of natural hazards, which in certain literatures, are known as causative factors. Some of the criteria have been derived directly from the Digital Elevation Model (DEM) while some have been obtained from the combination of the DEM with an empirical formula in the GIS environment to be transformed into digital layers.

In addition to the predisposing criteria, this study also utilized a geological terrain map which have been developed by the Mineral and Geoscience Department (JMG). The terrain map classified particular terrains in the form of classes, which are class I, class II, class III, and class IV [23]. The different classes has different implications on geotechnical limitations, suitability development, and others. This geological terrain map has been supplemented with utilization of other relevant parameters from predisposing criteria to augment assessments. Van Westen [24] listed all the possible triggering factors such as rainfall, earthquakes, temperature, wind speed and direction, wave height, tides, and volcanic eruptions that could trigger the occurrences of different types of natural hazards. In Malaysia, the distribution and intensity of rainfall is an accelerating agent in landslide occurrences [25]. The total rainfall and the higher degree of annual temperature accelerate the weathering process, as it will be able to break through 100 m into the ground thus producing a large-scale landslide [26].

In addition to elevation, the slope material's strength and cohesiveness such as highly weathered granite and metamorphic foliation as well as the amount of friction acting on the material play a very important role in increasing the landslide susceptibility. On the other hand, the basic cause of floods in Malaysia is the incidence of heavy monsoon or convective rainfall and the result of a large concentration of runoff, which has been exacerbated due to rapid development in the river catchment areas and the deteriorating river's water holding capacity [27]. Therefore, rainfall has been identified as a key factor for hazards in this study. Information on element at risk will later be extracted from the land use maps, satellite images, and various sources collected from many departments, as it is essential in determining the extent of the vulnerability of the study area. Table 1 demonstrates the tabulation of all the required information to derive a qualitative hazard map. However, some of the information is still in the process of being updated to current data. Thus, only the available criteria have been transformed into digital layers.

TABLE I. LIST OF REQUIRED DATA

Factors	**Criteria**		**Sources**
	Landslide	***Flood***	
Predisposing criteria	Slope Elevation Topographic wetness index	Slope Elevation Drainage density Stream power index	Digital elevation model (DEM)
	Erosion Morphology & slope geometry Terrain characteristic Lithology Geological terrain class Soil Series	Morphology & slope geometry Lithology Soil Series	Minerals & Geoscience Department; Department of Agriculture
		Land use	Satellite img.
		100-yrs flood data Flood prone area	Department of Irrigation & Drainage; Public Work Department
Triggering factors	Precipitation data		Meteorological Department
Element at risk	Buildings Road Essential facilities Demographic		Landuse map; satellite img.; Kajang Municipal Council; Social vulnerability map

Spatial analysis is performed in a GIS environment using the digital layers of the predisposing criteria for both landslide and flood whose weightage will be assigned by utilizing indexes from expert judgement. These efforts will be integrated through a model for developing a qualitative hazard map. A vulnerability map will be derived through the integration of the parameters from the element at risk. To ensure a comprehensive study, the social aspect through the social vulnerability index will be quantified to provide further understanding of the dynamic characteristic of the human dimension underlying the social vulnerability. Since there are challenges in conducting the social vulnerability study in the home institution, one of the author went for social vulnerability training at the University of the Philippine, Los Baños [28]. The method used, ideas and knowledge gained from the scientific and social vulnerability study from the training institution will be employed and modified based on the suitability of the geographic and socio-demographic condition of the study area. An integrated disaster risk map will be derived based on the spatial analysis of both the landslide and flood qualitative hazard map with a social vulnerability map.

IV. Preliminary Result and Discussion

This study is an ongoing process and some results have yet to be compiled. Preliminary analysis of the land cover reveals, that there are noticeable condition of land cover changes in the years 1988, 1996, 2005, and 2014 (Figure 2). According to Reza [29], in 1988, most of the areas were covered by commercial agriculture as well as a forest area while the built-up area was less; in 1996, the earlier agricultural area had shifted to a forest based area while the built-up area was seen to have expanded. In 2005 and 2014, the built-up area had expanded significantly and commercial agriculture had become smaller and some of it had been shifted to a forest area. Consequently, the rapid expansion of the built-up area is believed to be one of the reasons that increase of the incidence of natural hazards.

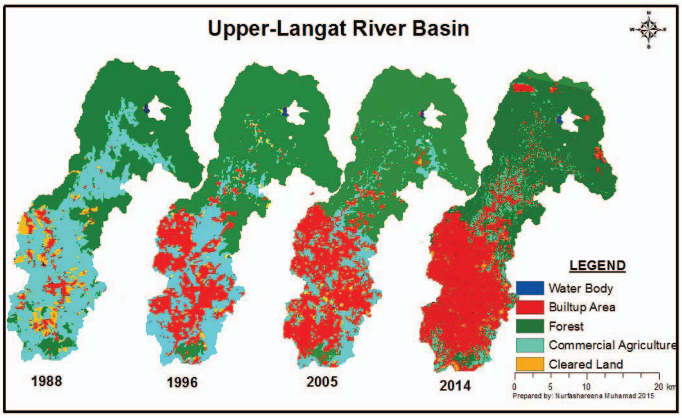

Figure 2. Land use and land cover map of the Upper-Langat River Basin

Such expansions might also influence the hydrological processes in the basin and accentuate the occurrences of natural hazards. As we can see, there are significant differences between the upper part and the lower part of the study area. Previous literatures clarified the upper part of the study area as mountainous [20], a unique morphology such as hills with ridges, isolated hills, and a rolling topography which has been categorized as hilly area in the Langat River Basin [30]. Van Zuidam [31] described a mountainous area is very steep and characterized by high mountain tops with elevations ranging from 500 m to 1500 m. So far the study revealed, this area has yet to experience any major development and only has a few small townships such as Pekan Batu Lapan Belas. Most of the lower part of the study area has an elevation of below 150 m where most urbanization activities take place. Increasing human activities and rapid developments have caused landslide and flood occurrences to accumulate within this area. Major development activities along the river stream have resulted in the increase in size and frequency of floods in particular [32].

To develop an inventory, locations of the landslides and flood occurrences have been identified and plotted onto a map as depicted in Figure 3a. The past occurrences of landslide that were collected from the archive, began from 1994. Meanwhile, the latest occurrences until 2014 were gathered from the municipal council and other related departments. Extensive field works were done to update and record the coordinate locations. The shaded relief map illustrates that the landslide locations are scattered but they occur mainly in the area that appears rough in the map indicating a hilly or sloping topography. Utilizing the terrain geological map from JMG, it is evident that most of the landslides occurrences occurred at terrain class II, III and IV. However, there are also occurrences at the terrain class I. In addition to that, a study from Muhiyuddin [30] explained that landslides in the upper-Langat river basin usually happen at elevations of between 20 m to 500 m due to the rapid urbanization. Meanwhile, a recent study by Abd. Manap et al. [33] characterized the areas with elevations of between 100 m to 500 m as steep slopes. Although landslides are often associated with higher elevations, it can also occurs at low topographical areas [34]. Therefore, the identification of the predisposing and triggering factors of landslides is very important.

Meanwhile, the flooded area is mostly accumulated in the middle part, along and adjacent to the main river that appears smooth in the map, indicating flat areas or areas with low elevation (Figure 3b). Major development activities along the river stream have resulted in the increase of the size and frequency of floods in particular [32]. Similarly, in the case of landslides, past occurrences of flood were gathered from the archives, previous literatures, and government agencies beginning from 1991 with the latest in 2014. Field checking was also carried out to capture the coordinates. Additional spatial information of 100 years flood data obtained from the Department of Irrigation and Drainage and flood prone areas data obtained from the Public Work Department were utilized to observe the patterns of flood events. Most of the occurrences fell in the flood prone areas mainly in Hulu Langat, Cheras, and the Kajang town. Due to the frequent occurrences of flood in the Kajang town, field investigation was conducted to determine the coverage of the inundated area from 1999 until the recent flood in 2014. Initial findings revealed that the size coverage of the inundated area in 2014 was smaller compared to the previous years (Figure 3c).

In order to provide a more effective decision making input for disaster management, a holistic risk mapping that would incorporate physical and vulnerability elements is necessary. In developing the vulnerability map, a social vulnerability data is an added-value during the process of mapping the element at risk. Thus, the integration of the obtained qualitative hazard map and vulnerability map through the overlay function in spatial analysis will provide an integrated disaster risk map, which will visualize the risk areas ranging from extremely high risk areas to low risk areas.

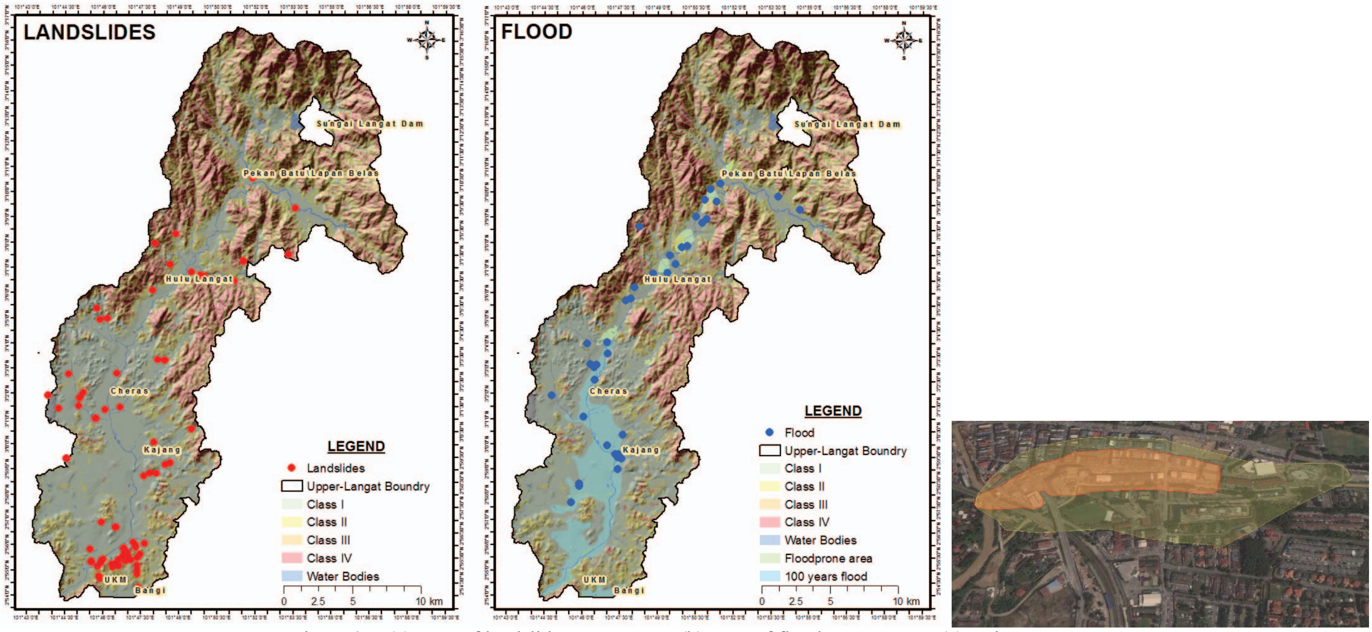

Figure 3. (a) Map of landslide occurrences, (b) Map of flood occurrences, (c) Kajang Town

V. CONCLUSION

The increasing demands of urban dwellers in term of housing, infrastructure, transportation, and others are to fulfill their needs and dignity. As a result, the anthropogenic activities are escalating in the ecologically fragile and sensitive areas such as floodplain areas or hill slopes. Extreme precipitation makes the urban areas located in the floodplains and highlands susceptible to disasters. This phenomenon reflects the importance of appropriate land use planning in order to prevent disasters. An integrated disaster risk map has facilitated the effort of reducing disaster risks to a certain significant extent. Focusing only on the physical aspects are certainly inadequate in preventing disaster if the social aspect of vulnerability assessment is largely ignored in urban settings. This is because the social aspect is the most apparent after the occurrence of disasters as different patterns of damages, losses, and suffering may be experienced by certain groups of the population.

Thus, integrating the physical and social aspect will generate a holistic output which will provide assistance and it has an immense potential as a decision making tool. Such tools may be able to enhance the competence of decision makers in regards to reducing risk, vulnerability, and the impact of disasters. As this study is an attempt to bridge science and policy through the efficient use of scientific data and to communicate it for planning purposes and decision-making, the obtained output is later anticipated to form the basis of many important assessments, i.e., calculation of loss and damage. This effort also attempts to promote the use of geo-information technology for disaster management initiatives to the decision-makers and other stakeholders. Evidently, geo-information technology particularly the GIS has demonstrated that most operations in hazard management can be accomplished efficiently to support disaster risk reduction in urban areas which are cost effective, simple, and useful.

VI. FUTURE WORK

The study will proceed with the hazard modelling to analyze the predisposing criteria to produce a qualitative hazard map for both landslides and floods. Ranking and weighting for the predisposing criteria will be assigned first before it can be modelled. Then, the on-going process to complete the social vulnerability assessment including identifying a suitable social vulnerability index, a model to deliver the index, social vulnerability indicators, and other potential aspects can be incorporated once they are detected as vital factors for deriving the vulnerability map. Finally, a qualitative hazard map of both landslides as well as floods and a vulnerability map will be analyzed through the overlay function to develop an integrated disaster risk map. Consequently, the research finding will be shared with the Office of the State Secretary of Selangor and the local authority of Kajang, Selangor in supporting effective disaster management decisions for urban area.

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