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Vulnerability and adaptation of urban dwellers in slope failure threats – A preliminary observation for the Klang Valley Region

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Abstract

This paper discusses the outcome of a research that examines the relationships between vulnerability and adaptation of urban dwellers to the slope failure threat in the Klang Valley Region. Intense urban landuse expansions in the Klang Valley Region have increased urban dwellers vulnerability to slope failures in recent years. The Klang Valley Region was chosen as the study area due to the increasing intensities and frequencies of slope failures threat. This paper examines urban dwellers vulnerability based on their (1) population and demographics characteristics, (2) the state of physical structures of dwellings and (3) the situation of the immediate environment threatened by slope failures. The locations of slope failure incidents were identified, mapped and examined followed with a detailed field study to identified areas. The results identified significant relationships between vulnerability indicators and slope failures in the Klang Valley Region. The findings of the study are envisaged to give valuable insights on addressing the threat of slope failures in the Klang Valley Region.

Key words

Slope failures, Vulnerability, Adaptation, Urban dwellers, Klang Valley Region

Introduction

This article examines the vulnerability and adaptation of urban dwellers to slope failure threats in Klang Valley Region (KVR). Most slope failure studies examine the physical dimensions of the slope failure process – response regime (Raj, 1998; Lee and Jasmi, 2005; Gue and Liong, 2007) while the human impact dimension was grossly lacking. The urban settlements threatened by slope failures were observed to be located on gentle to very steep slopes in KVR. Slope failures in the KVR contribute too much damage to household properties and incurred many loss of lives amongst the urban dwellers. Slope failure frequencies had increased in the past decade in the KVR and this is equivalent to the national and regional experiences of slope failure incidences. A total of 146 slope failures incidences were recorded in the KVR, 41% of which occurred during the periods 2004 to 2008 as shown in Fig. 1. This article discusses the human dimension of slope failure threats - human vulnerability and adaptation to slope failure threats. The research focuses in areas where exists only high slope failure risks in the KVR.

Hazard and risk analysis have been studied to examine the impact of slope failures. Chau *et al.* (2004) used landslide inventory and GIS to examine slope failure hazards in Hong Kong. In this study, human and natural variables such as geological, geomorphological, population, climatic conditions and rainfall data were investigated. Guzzetti *et al.* (2005), proposed a probability model to understand slope failure hazards in the Staffora river basin in Northern Apennienes, Italy. The geomorpho--hydrological variables together with lithology, structural and land use variables were used to determine the hazard of slope failures. Guzzetti *et al.* (2005) explained the relationships through the use of mathematical modelling. Harp *et al.* (2009) mapped slope failure hazards by using rainfall indices in Honduras and Micronesia. These studies were more interested in integrating the causative factors of slope failures to develop hazard and risk maps so that guidelines can be used to quantify hazard and risk for purposes of slope failure zoning such as that proposed by Fell *et al.* (2008). Although these hazard and risk zoning reveals the slope failure susceptible areas, not much attention was given to human vulnerability to slope failures. Similar situation was observed in Malaysia where slope failure processes were mainly investigated in studies by Tan and Chow (2004), Gue and Liong (2007), Liew (2004); structural mitigation (Gue and Tan, 2002), and slope risk assessment (Suhaimi *et al.*, 2006).

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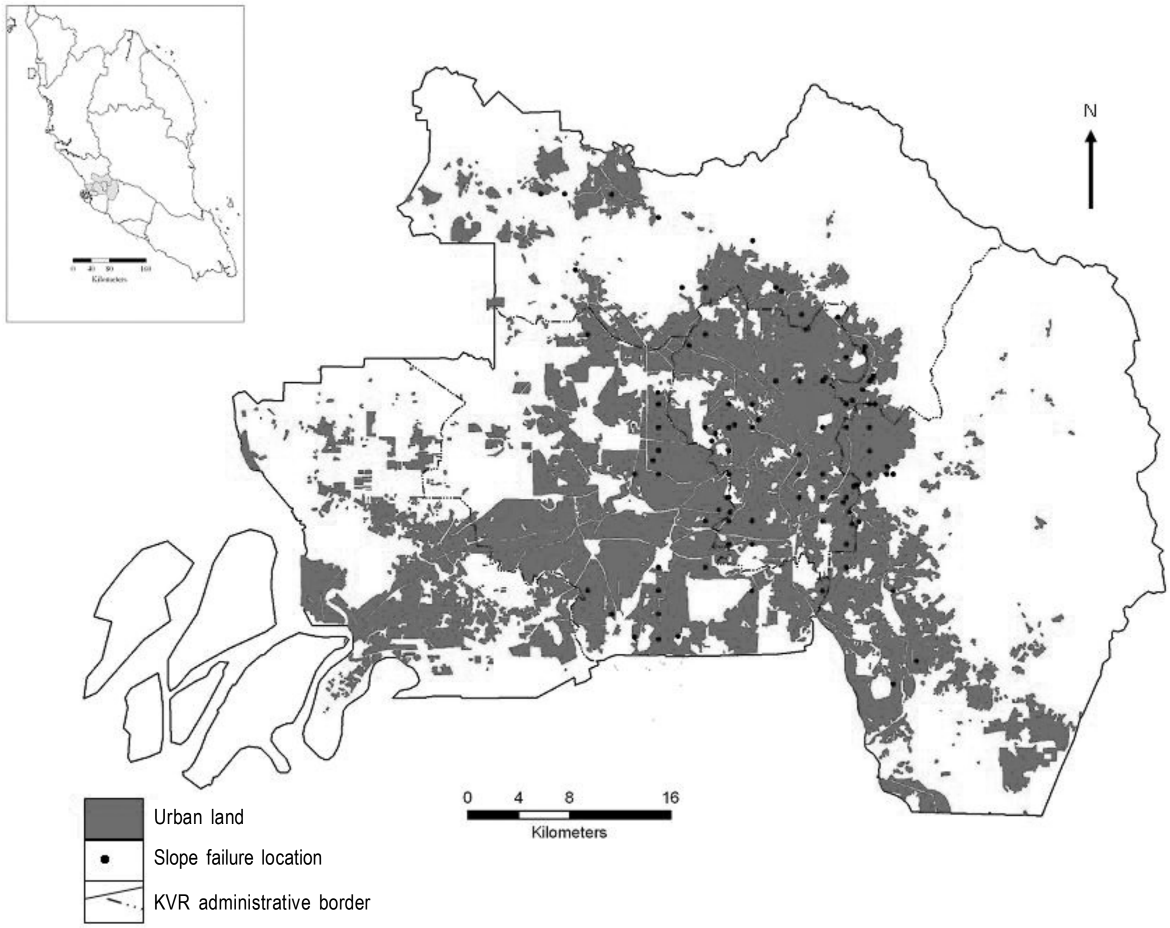

Fig. 1: Distributions of slope failure in the Klang Valley Region, Peninsular Malaysia

However, population vulnerability to slope failures was given limited priority.

In fact, the term 'vulnerability' is generic and is applicable to various hazards that pose dangers to humans. Therefore, the definition of vulnerability by Turner II BL *et al.* (2003) can be adapted to explain vulnerability to slope failures *i.e.* the degree of the people experiencing harm in the slope failure incidents, hence giving it a more precise meaning when related to slope failures. There are many models of vulnerability and climate change researchers have developed models of vulnerabilities (Turner II *et al.*, 2003; Smit and Wandel, 2006). The similarity between these vulnerability models are in the components of vulnerability *i.e.* exposure and sensitivity and adaptation. These components are inter-dependant and show strong inter-relation with the system at risk (community in threat). In conclusion, based on these models three aspects *i.e.* threat, system at risk and adaptation are identified as the main components in human vulnerability models.

In conducting research on system at risk, Van Westen *et. al.* (2008) included building, transportation networks, lifelines, essential facilities, population data, agriculture data, economic data and ecological data in vulnerability research. However, O'Hare and Rivas (2005) examined vulnerability of the urban community in La Paz city in Bolivia by focusing on the aspect of population pressure. In this study, O'Hare and Rivas highlighted that economically marginalised people who occupied self-built settlements as the most vulnerable people to slope failures in La Paz city. This finding supports the earlier study conducted by Chardon in 1999. Chardon explained marginal dwelling in shantytowns exposed to natural hazards that include slope failures in many Latin America cities. Cutter *et al.* (2003) introduced age, gender, health, income, type of dwelling unit, and employment variables under social vulnerability. However, other less empirical studies have also been conducted to quantify human vulnerability to slope failures.

Anderson *et al.* (2008), Lin *et al.* (2008), as well as Carmen-Solana and Kilburn (2003) also conducted studies on adaptation to slope failure. Anderson *et al. (2008)* conducted a pilot study to reduce the risk of slope failures in unplanned settlements on steep slopes in the Caribbean. This study suggested that awareness of good drainage is a cost-effective measure that will help to increase the adaptation of vulnerable groups to slope failures. On the contrary, the populace in Barranco de Tirajana basin are aware of slope failure consequences but overlooked the potential hazard and 50% of the respondents were not sure as to what to do during the onset of emergencies (Carmen-Solana and Kilburn, 2003). In view of this, investigation in slope failures should be applied to a wider approach by incorporating human vulnerability. Exposure to slope failures is unlimited to a particular society or group. Thus, the need to understand occurrences of slope failures, their nature of impact and need for mitigation measures is becoming essential especially in the KVR.

The study was carried out in the KVR (3° 0'N - 3° 15'N; 101° 23'E - 101° 51'E; 3° 0'N) which is located in state of Selangor in Peninsular Malaysia (Fig. 1). KVR recorded 43% slope failure entry in Peninsular Malaysia even though it occupied an area of 2831 km^2 only. Thus, KVR is selected based on the frequency of slope failures and is therefore suited for investigating vulnerability to slope failures.

Materials and Methods

The present study used primary and secondary data to accomplish the objectives of the present study *i.e.* 1) examining vulnerability of urban dwellings to slope failure hazards, (2) investigating adaptation measures and (3) developing a model of urban dwellers vulnerability to slope failures. The frequencies and distribution of slope failures were gathered from press materials and slope failure reports prepared by various governmental and non-governmental agencies involved with slope failure mitigation and management measures. The sampling method applied in this study is shown in Fig. 2 whereby slope failure occurrences were identified from press report and professional slope failure reports. Then to identify causative factors and distribution, slope failures from 2006-2008 were screened and sorted out. Subsequently, by using this slope failure list and the 'slope failure risk map' provided by the Malaysian Centre for Remote Sensing (MACRES), the slope failure risk settlements in the study area were identified. However, the slope failure risk map was only used to identify the risk area and the exact location for survey sample was identified using occurrences of slope failures during 2006 to 2008. Besides, re-occurrences of slope failure were also taken into consideration during the selection of slope failure-threatened locations, which were identified from the slope failure inventory.

On the other hand, investigation of causative factors too enabled the identification of the critical parameters in selected highly slope failure-threatened locations. Next, the vulnerability components were identified through field observations, interviews with engineers and geologist, and by conducting survey questionnaire among the slope failure-threatened urban residents in the selected locations such as in Taman Bukit Mewah, Wangsa Height and Jalan Wangsa 9 in Bukit Antarabangsa; Bukit Kinrara Puchong; Mutiara Court, Cheras; and Bukit Damansara. The respondents of the survey questionnaire were the victims and dwellers in the neighbourhood of the slope failures in the study area from 2006 to 2008. A pilot study prior to distribution of survey questionnaires ensured reliability and validity of the questionnaires. During data collection survey questionnaires were distributed personally by hand to the residents or to their maids when the residents were not available. The survey questionnaires were left in the post box when the residents could not be contacted. From the total 400 questionnaires only 188 respondents responded completely to the questionnaires. Finally, the study used descriptive analysis to present the findings.

Results and Discussion

The study examined two fundamental components in slope failure hazards *i.e.* vulnerability and adaptation. The vulnerability component was scrutinized by analyzing the critical parameters and dwellers vulnerability indicators to slope failures.

Critical parameters: The study showed that there are many inter-related factors that act in weakening slope strength but more prominent localized factors were identified for KVR. Critical parameter of human vulnerability was determined by environmental and human entities. The environmental parameters were grouped into active and non-active environmental stress. The study found that rainfall, artificial vibration, load increment and vegetation as the main active environmental stress. While load increases (population, build-up areas), slope alteration and de-vegetation were identified as human parameters that greatly affected human vulnerability in the study region.

Vulnerability indicators: The number of occupants, household income, and their educational level were analyzed as vulnerability indicators. Households with less than 3 consist of 18.7 and 67.3% premises were used by 3 to 6 people, while 14% of the dwellings were inhabited by 7 and more people. House hold income on the other hand, showed 42.5% of the respondents earning RM3000 or less. A total of 38.4% respondents earned between RM3001 to RM12000 monthly. Amongst them, 10.2% received a household income of RM12001 to RM21000 whilst the rest of the respondents earned more than RM21001. The survey findings indicate that 65.4% of the respondents possessed higher educational level *i.e.* minimum educational level of bachelor degree. Only one respondent in this survey was not educated. Besides, the study found that 15% of the respondents were senior citizens of 60 years and above.

Besides the internal vulnerability of urban dwellers, the study also observed the external vulnerability of urban dwellers to slope failure in the KVR (Table 1 and Fig. 3a,b). Location of buildings was one of the variables investigated. For example, buildings located on the crest (hill top) face threat of slope failures. Buffer zones in Athenaeum Towers, Wangsa Height, Bukit Kinrara and Bukit Sg. Puteh were reduced in size as slope failures-threatened these areas. The same condition was noticed in Pudu, Wangsa Maju and Setapak slope failure areas. Meanwhile, concrete buildings were built in all the locations except in Kerinchi and Setapak where wood was also used to build houses.

a. Dweller awareness on slope failure threats: In this study, the awareness on the impending threat was measured through the

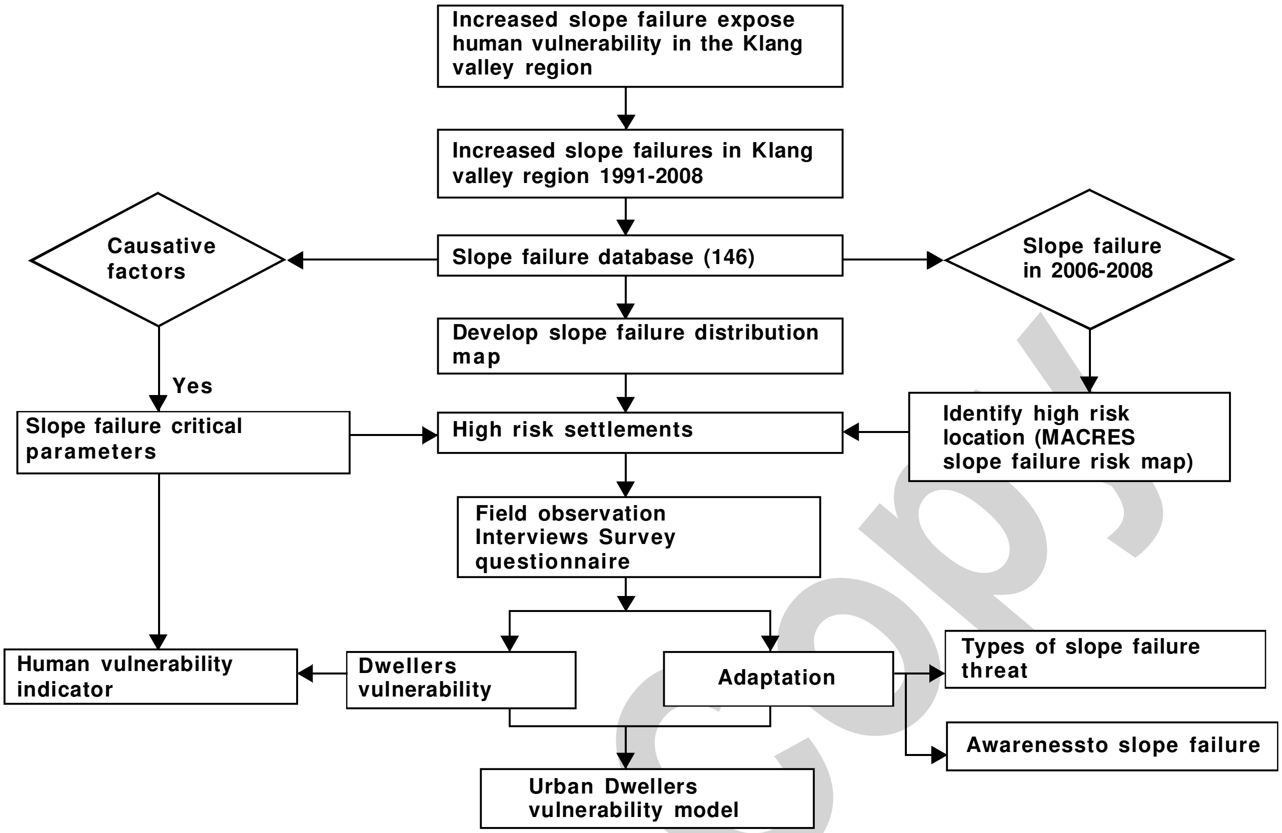

Fig. 2: Research sampling methods

perception on slope failure threats. The survey showed that 22% of the respondents assumed that their dwellings are located in safe areas while the rest were aware that their area is exposed to medium and high risk slope failures.

b. Dwellings insurance coverage: The survey showed that only 19.7% of the respondent had bought dwelling insurance while the rest were unaware of the existence of insurance coverage for natural disasters or slope failures.

Vulnerability has heterogeneous characteristics (Alca´ntara-Ayala, 2002) and its characteristics vary spatially and temporally. In view of this, International Strategy for Disaster Reduction (ISDR, 2006) specified that vulnerability differ between regions but cannot be a part of ongoing development. In the KVR, urban activities are ongoing and thus, contribute to the rise in critical parameters that increase populace vulnerability to slope failures. These critical parameters in vulnerability are an amalgamation of natural/ environmental parameters and human-related parameters. In a study, Jiménez Díaz (1992) found that torrential rain could significantly trigger slope failures where squatter areas located on precarious failure-prone slopes in Caracas. Human concentration on the squatters generated pressures which according to Jiménez Díaz (1992) contributed to slope failures. In a similar study, Smyth and Royle (2000) supported Jiménez Díaz (1992) arguments. Poverty is related with location of dwellings in slope failure-prone areas in urban areas in developing tropical countries. Dwellers are aware of slope failure threat but their preferences in dwelling choice are limited due to the economic incapability. In addition, natural factors such as gradient becomes threat when the slopes are altered (cut or/and filled) to cater human activities such as structural buildings, telecommunication and transportation network constructions, and quarrying activities. The construction of structures *i.e.* urban development (O'Hare and Rivas, 2005) and population pressure on slope surfaces increase loads (Cross, 2001) which could contribute to slope instability. Besides this, rain and gradient factors (Dai *et al.*, 2001) help to develop high energy region in KVR. High intensity torrential rainfall also rise loads on the surfaces and sub-surface of slopes which consequences in the reduction of the slopes' shear strength. Eventually, the whole process contributes to escalating vulnerability of urban dwellers and dwellings to slope failures in the KVR.

Urban vulnerability to slope failures renders 2 pertinent components *i.e.* internal and external vulnerabilities. The indicators of internal vulnerability are age, household income, number of occupants and educational level variables. According to Cutter *et al.* (2003), elderly and very young children were more vulnerable towards natural hazards. On par with this, the study found, especially in Bukit Damansara and Mutiara Court in Cheras, that senior folks (age more than 60 years), young babies and maids were the ones who occupied the dwellings most of the time. Other internal factors

(a) Mutiara Court apartment (b) Taman Melawati

Fig. 3a,b: External Vulnerability Indicators - Precarious dwelling locations

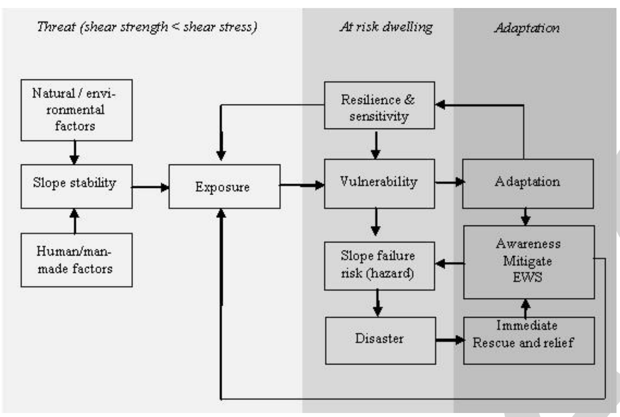

Fig. 4: Vulnerability to slope failures in the KVR

such as level of education have significant effect on the selection of types of dwellings while household income influenced the capacity of victims to recover from disaster (ISDR, 2006).

On the other hand, external vulnerability was measured from the perspective of the characteristics of the dwellings location, availability of buffer zones, types of buildings and building materials. Town and Country Planning Department's guide book (2001) states that buffer zone is required for structures next to slopes of more than 70 degrees. The required buffer zone should be of at least the height of the slope *i.e.* between the slope and the building on the foot or crest of a hill. Buffer zones are required in other slopes as well because slope failures in the urban areas occur on all degrees of gradients. Furthermore, the types of slopes and material will contribute to the level of vulnerability. Collins (2008) stated that debris flows increase in fill slopes hence the need for increased buffer zones. Another contributor of external vulnerability is the height of the building. The height of building will marginalize the resistance to gravitational loads (Roca *et al.*, 2006). When the height of a building increases, the number of vulnerable people is also increased. For example, in the incident of high-rise building of Highland Towers Condominium, a total of 48 people and a rescued victim were confirmed dead due to slope failure (Ngai, 1998). Regarding the material of slope failures, O'Hare and Rivas (2005) found that self-built informal houses were more vulnerable in La Paz Bolivia. The settlers in this area were economically marginalized group of people and as such, their adaptation capacity was also very low. In another study by Papathoma *et al.* (2007), poor material buildings with one floor and without surrounding wall, as well as large windows facing slopes is revealed as more vulnerable which in turn influences human vulnerability as well.

Both urban dwellers adaptation and adaptation measures taken by slope failure management groups are essential in tackling slope failure vulnerability in urban areas. The adaptation of dwellers to slope failures focused in the study found that less people were aware on the option of insurance coverage for natural disasters in the study area. In addition, 22% dwellers who responded to the survey questionnaire indicated that their neighbourhood was safe and there is no risk of slope failure in their area. The rest of them showed awareness of slope failure threats in their settlement. The finding in the KVR is similar to the finding of Carmen-Solana and Kilburn (2003) and Lin *et al.* (2008). The respondents in these studies too were aware of the threat of slope failures or flood but assumed that they were not the vulnerable group to these hazards.

The vulnerability and adaptation of urban dwellers in slope failures-threatened areas were studied in the research in KVR. Urban development amplified the danger of slope failures which eventually increased the vulnerability of urban dwellers in this region. Critical parameters in vulnerability to slope failures, vulnerability indicators and dwellers adaptation were studied and modelled in Fig. 4. The major component *i.e.* threat, system at risk and adaptation of the vulnerability study was outlined in this figure. The threat in this study is slope failures which were initiated by the environmental factors and aggravated by human activities such as urban activities, transportations and constructions. Thus, the threat become risk to the system *i.e.* the populace on the vicinity of hazardous slopes were exposed to slope failures. However, protection to the system came from resilience contributed by adaptation, awareness, slope

Table - 1: External vulnerability to slope failures

Location	External vulnerability			
	Location	**Buffer zone**	**Building types**	**Building material**
Athenaeum Towers	Crest	✓	High rise – condominium	Concrete
Kerinchi	Down hill	X	Self-built	Wood &/ Concrete
Mutiara Court	Middle hill	✓	High rise - low cost	Concrete
Setapak	Low land	X	Single/ self-built	Wood &/ Concrete
Taman Bukit Mewah	Down hill	X	Bungalow/ semi-D	Concrete
Taman Bukit Permai	Crest	✓	High rise - middle cost/ terrace	Concrete
Taman Melawati	Down hill	X	Bungalow/ semi-D	Concrete
Taman Segar	Middle	✓	High rise - low cost	Concrete
Wangsa Height B. Antarabangsa	Crest	✓	High rise - low cost	Concrete
Taman Harmonis	Down hill	✓	Bungalow	Concrete
Taman Zooview	crest hill	X	Terrace	Concrete
Kg. Pasir	Down hill	X	Squatter houses	Wood
Jalan Sultan Salahuddin	Middle hill	✓	Terrace - government quarters	Concrete
Medan Damansara	Down hill	X	Terrace	Concrete
Bukit Chinchin	Down hill	X	Self built-single	Concrete
Wangsa Maju	Low land	✓	High rise - low cost	Concrete
Pudu	Down hill	X	High rise - government house	Concrete
Bukit Sg. Puteh Ampang	Down hill	X	Single self – built	Concrete
Bukit Kinrara	Crest	X	Terrace	Concrete
Pantai Dalam - Bukit Gasing	Down hill	X	Long house	Concrete
Highland Towers	Middle hill	✓	High rise	Concrete

(* only vulnerable settlements to slope failure are selected). (✓) Available, (X) Not available

failure early warning and other short- and long-term mitigation measures. The impact of slope failures can be reduced by researchers, policy makers, stakeholders as well as the general public by resolving arising problems step by step.

Physical conditions and human activities in the KVR induced slope instability. Human activities such as construction works, telecommunication and transportation activities and/ or quarrying activities generate artificial vibrations in the study region. On top of this, changes in land use leaves urban lands that transform the natural condition of slope and increase load on slope. The condition is further aggravated by population pressure which is boosted by the economic conditions of the region which eventually contributes to increase of population vulnerability in slope failure susceptible areas in the KVR. Vulnerability to slope failures is examined by internal and external indicators as well as awareness to slope failures which could reduce fatalities in the urban areas if necessary actions are taken. Therefore, the findings in this study are expected to enables the public, scholars, geologists and engineers to be more aware of the risk of slope failures that the urban dwellers are exposed to and subsequently take necessary measures to reduce the level of vulnerability amongst the slope failure threatened vulnerable populaces in the KVR. Moreover, the findings further enhance awareness on requirement of suitable adaptations to slope failures hazards in the study region. The knowledge generated through this research could therefore encourage future studies on human vulnerability to slope failures which will eventually assist policy makers in making effective decisions on slope development.

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