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Socio-Economic Impact of Riverbank Failure at Kg. Pohon Celagi in Pasir Mas, Kelantan, Malaysia

Kesan Sosio-Ekonomi ke atas Kegagalan Tebing Sungai di Kg. Pohon Celagi in Pasir Mas, Kelantan, Malaysia

See Too Kay Leng, Mokhtar bin Jaafar, Frankie Marcus Ata* &
Mohd Ridhuan bin Mohd Jamil

ABSTRACT

Riverbank failure is a geological phenomenon that occurs when the soil or rock comprising the bank of a river collapses, leading to the rapid erosion of land and the formation of large cracks and sinkholes. While it is a natural occurrence, riverbank failure can have severe consequences for nearby communities and the environment. A massive riverbank failure occurred along the Kelantan River in Kampung Pohon Celagi, Pasir Mas, Kelantan, Malaysia. In this study, the affected area of the riverbank failure was determined and the effects of the bank failure on the village socio-economics and community were investigated. This study utilized interview methods and field observations to collect data and information. The study shows that 0.58 km^3 land in the village was affected by the riverbank failure. The local authorities designated the 50-m range from the riverside as the red zone where most houses and buildings collapsed with the riverbank movement, and the parameters were 51–100 m is the high-risk area, 101–150 m is moderate, and ≥ 151 m upwards is low risk area, respectively, from the riverbank. The affected communities were required to move to safer areas and leave their properties to be demolished or failure with the riverbank. Socioeconomically, businesses around the disaster area were affected as they were prohibited from operating in the high-risk area. Overall, the disaster resulted in the local communities losing their property and experiencing depression. As a result, it is expected that all stakeholders will work together to develop a solution that ensures the well-being and safety of the community from riverbank failure.

Keywords: Riverbank failure; disaster; community and socio-economic

ABSTRAK

Kegagalan tebing sungai merupakan fenomena geologi yang berlaku apabila tanah tebing sungai runtuh hingga menyebabkan pergerakan tanah yang cepat dan membentuk retakan. Walaupun ia merupakan kejadian hakisan morforlogi semulajadi, kegagalan tebing sungai boleh memberi kesan yang serius kepada komuniti dan alam sekitar. Satu bencana kegagalan tebing Sungai Kelantan telah berlaku di Kampung Pohon Celagi, Pasir Mas hingga mendatangkan impak yang besar kepada penduduk dan sosioekonomi setempat. Objektif kajian ini adalah untuk mengenal pasti keluasan kawasan yang terjejas akibat kegagalan tebing sungai. Selain itu, kajian juga bertujuan untuk mengkaji kesan kegagalan tebing sungai terhadap sosioekonomi terhadap penduduk yang terjejas. Kajian ini menggunakan kaedah temu bual dan pemerhatian lapangan untuk mengumpul data dan maklumat kajian. Teknik analisis yang digunakan adalah deskriptif analisis. Hasil kajian menunjukkan bahawa keluasan sebanyak 0.58km^3 di kampung tersebut terjejas akibat daripada kegagalan tebing sungai. Pihak berkuasa tempatan menetapkan zon merah sebagai kawasan yang paling berisiko, iaitu jarak 50 meter dari tebing sungai di mana kebanyakan rumah dan bangunan di lingkungan kawasan ini runtuh akibat pergerakan tebing sungai. Lingkungan kawasan dari tebing sungai 51-100 meter adalah kawasan berisiko tinggi, 101-150 meter sebagai kawasan sederhana, dan 151 meter keatas adalah kawasan berisiko rendah. Penduduk yang terjejas dikehendaki berpindah ke kawasan yang lebih selamat seperti rumah saudara mara atau pusat permindahan sementara. Mangsa dikehendaki meninggalkan harta benda dengan segera agar tidak mengancam nyawa atau mendatangkan kecederaan, manakala rumah mangsa akan diroboh atau runtuh bersama tebing sungai yang tidak stabil. Dari segi sosioekonomi, perniagaan di sekitar kawasan bencana terjejas teruk akibat larangan oleh pihak berkuasa untuk beroperasi di kawasan berisiko tinggi. Secara keseluruhan, ramai penduduk di kampung tersebut kehilangan harta benda dan mengalami tekanan akibat bencana. Oleh itu, semua pihak berkuasa harus mencari cara penyelesaian untuk memastikan kesejahteraan dan keselamatan komuniti daripada bencana kegagalan tebing sungai.

Kata kunci: Kegagalan tebing sungai; bencana; komuniti dan sosioekonomi

INTRODUCTION

River morphology is subject to a system that ensures that the river is balanced. System interactions may result in varied dynamic activities within the river system, such as sediment suspension, river water filtration by water plants (marshes and riverbank erosion), which is a reaction of the river morphology system. Riverbank erosion results from the natural system or human activity and can lead to riverbank mass failure, which has a wide range of negative consequences for humans and the environment. Many factors contribute to river mass instability and failure, such as riverside development, river stream exploration, forestation, and sand mining. Consequently, the number of riverbank failure or failure cases has significantly increased for example, riverbank failure cases at Kg. Kusial, Tanah Merah; Kg. Kemubu, Pasir Mas and Kg. Kasa, Pasir Mas (See Too 2018).

Riverbank failure has received much attention recently as it results in immense damage to nature and humans. Riverbank failure occurred frequently in the wide valley desert reach of the Upper Yellow River, China, which led to increased disasters, such as floods (Shu et al. 2012). The Ningxia government reported that the riverbank failure disaster affected approximately 20,000 people. The riverbank failure also resulted in high government costs to compensate land owners pre-acquisition to repair the failured riverbank. Hence, riverbank failure is a disaster that has negative consequences caused the government to lose money, harmed people, and altered the river morphology.

Severe natural disasters, such as riverbank failure, mudslides, and flooding are common in tropical countries, such as Malaysia. Living in a natural disaster-prone area is risky, specifically in the presence of non-eco-friendly development projects and the lackadaisical attitude of the agencies involved such as Department of Irrigation and Drainage, Department of Environment and so on (Joel and Mark., 2017). The Malaysian Department of Environment (2018) reported that the massive riverbank failure in Kampung Kemubu, Pasir Mas on 2018 was caused by river stream overexploitation by the local community. The causative factor was an incorrectly constructed levee by the Kemubu Agriculture Development Authority (KADA) that caused the river flow to drastically change and eventually hit the riverbank (Metro Harian 2018). Consequently, the riverbank was destabilised and the erosion caused unpredictable riverbank failure. The failure affected 12 families and 10 houses and forced the inhabitants to relocate to a safer setting. Although the local government compensated the victims' losses, they remained dissatisfied given their reliance on agriculture for income. The villagers' loss of their land and houses rendered it difficult for them to earn a livelihood.

A similar incident occurred in Kg. Pohon Celagi, Pasir Mas attracted the nation's attention because to the large number of victims affected. Morphological changes have a significant impact on the local community. However, the community and local government consistently questioned the risk zones before deciding to move victims and provide compensation. In addition, is it the riverbank failure has a socio-economic influence on the nearby communities has become the research question for this study. The consequences of riverbank failure disasters on the surrounding community should be extensively researched to get the fundamental idea before any development project to be make in the future.

The objective of the study is two-fold: 1. The purpose of this research is to determine the affected area of the riverbank failure. 2. The study intends to investigate the socio-economic and community effects of the riverbank failure.

LITERATURE REVIEW

The bank failure mechanism is complex and is a cutting-edge interdisciplinary academic research topic. As it stems from natural phenomena, such as erosion and deposition, river morphology is altered highly frequently over time. River regime instability and frequent erosion and siltation typically result from bank slope failure and present a serious threat to both river regulation and the livelihoods of inhabitants in the area. Bank slope failure is a natural occurrence that occurs frequently on both sides of alluvial plain rivers and is caused by combined factors where a review of riverbank soil failure in the United States and other countries determined water flow and riverbank soil structure as the most important influencing factors of riverbank failure.

Most current studies focused on the occurrence and development of bank failure and the critical stability conditions for different riverbank soil compositions (homogeneous- or binary-structure riverbanks) (Simon 2009; Davis & Harden 2012;

Stefano et al. 2003; Zhang et al. 2009; Jamieson et al. 2012; Papanicolaou et al. 2007; Zong & Xia 2013; Nardi et al. 2012) or did not consider the boundary conditions. Xia and Zong (2013) combined indoor geotechnical test results with nearshore hydrodynamic condition calculations and quantitatively analysed the soil characteristics, failure mechanism, and factors influencing the failure of the lower Jinjiang dual-structure bank of the Yangtze River. The outcomes of the study might shows the effect of different soil type can bring to the riverbank failure happen. This previous study also had proven that soil type in Kg. Pohon Celagi can be eroded easily because it is 90 % gravel sand (The National Disaster Management Agency Malaysia 2021).

There are two manifestations of the effect of water flow on bank failure: a change in the bank slope gradient alters the bank slope stability or a change in flow structure after riverbed deformation accelerates the occurrence of bank slope failure and the decomposition of landslides and their transportation (Nor Azlinda 2021). Transverse velocity and river width and water depth were proposed to be positively related. Notably, more concentrated nearshore velocity is followed by a greater lateral gradient of the nearshore velocity to the bank and that a steeper bank slope is more likely to lose stability and the bank will failure (Yu 2008).

Many researchers have investigated the characteristics of slope instability, also known as failure modes. Following Osman's stretching model (Puteri Azura et al. 2002) and considering the effects of pore water and hydrostatic pressure on bank slope stability and relaxing the requirement that the sliding surface passes through the foot of the slope, Darby and Thorne (1995) obtained highly realistic simulation results, which were extended to the straight reach stretching model. Fukoka (1996) scour-tested a binary-structure bank on a Shinkawa River floodplain in Japan by digging and discovered that clay failure prevented further water flow scouring of the slope foot.

Darby and Thorne (1995) proposed a channel broadening model based on the hydrodynamic soil mechanics method of homogeneous banks to calculate the lateral scour distance of a bank slope and determine whether the bank slope was unstable and would consequently failure. Yu et al. (2008) developed a generalized slope model based on the original sediment of typical bank failure sections in the middle and lower reaches of the Yangtze River, China and simulated the erosion mechanism and ultimate stability gradient of slope failure. Wang and Sun (2010) investigated bank stability under scouring action using the influence deviation and path damage theories and identified the bank stability evolution and prediction method. Zong and Xia (2013) established a bank stability calculation model to analyse bank failure from the perspective of water flow erosion or bank slope stability; however, the authors did not combine the two methods.

The primary external cause of bank failure is hydraulic action. Puteri Azura et al. (2002) investigated riverbed depth and riverbank scour and used the safety factor to determine whether the bank had failed. Secondary flow significantly increased the average shear stress of water depth by more than twofold (Papanicolaou et al. 2007). Jia et al. (2011) developed a lateral erosion model of flow slip bank failure and tested its correctness in a flume. Jamieson et al. (2012) investigated the effects of turbulence and vortices on bank failure and discovered that vortices and scouring zones were frequently in the same location. Moreover, an experiment was performed in a curved flume with six groups of tests to investigate the effect of near-shore riverbed composition on viscous bank slope failure under the same hydraulic action (Yu, 2016). This study were shows the similar situation and consequences with the study area which is affected local community's safety and socio-economic.

STUDY AREA

The monsoon season on the Eastern Coast of Peninsular Malaysia occurs from November to February. Generally, the average rainfall amount during the monsoon is between 1500 mm and 2000 mm. The state of Kelantan is on the East Coast experienced more serious rainfall events, specifically in February 2021, which affected the morphology and community settlements along the Kelantan River, particularly in Kampung Pohon Celagi, Pasir Mas. The village experienced a serious riverbank failure on 17 February 2021, which resulted in the loss of homes, damaged roads and agricultural land (Department of Drainage and Irrigation, DID, 2021) (Figure 1).

FIGURE 1. Local Community Moving to Safer Locations

Kampung Pohon Celagi is located at the centre of Pasir Mas town (Figure 2) at approximately 6° 02' 41" N, 102° 09' 00" E along the lower stream of the Kelantan River basin. The village consists of 72 houses and premises with 118 residents (Department of Irrigation and Drainage, 2021). The study area is opposite the meander of the Kelantan River, which flows through Pasir Mas. Although Pasir Mas experienced heavy rain every year during the monsoon, which caused floods, there had been no serious major riverbank failure. In February 2021, riverbank erosion spanning 1.93 km^2 occurred in Pasir Mas. The DID (2021) reported that the erosion was connected to underground water movement. The erosion spanned 23 days with an average 2.5 cubic tonnes of soil lost. The large amount of soil lost might have been due to the soil texture characteristic, which was sandy clay.

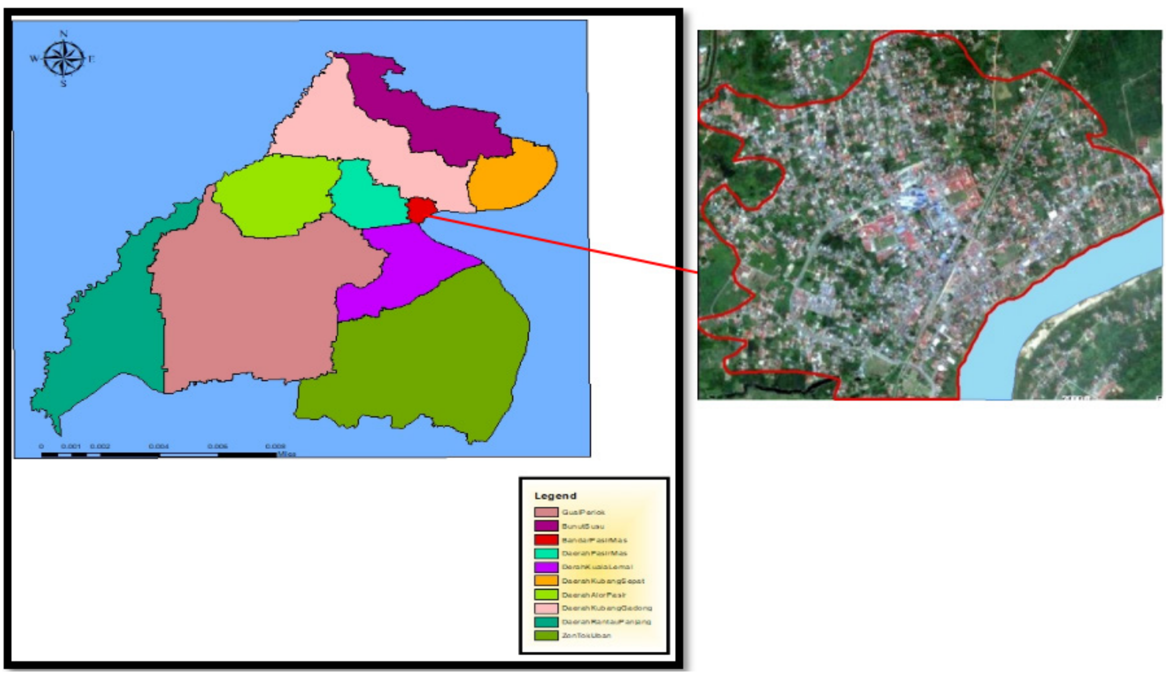

FIGURE 2. Research Location

METHODOLOGY

To answer the research questions, data and information were obtained through interviews (Focused Group Discussion) and a field survey. The research site was surveyed three times and a total of 10 victims were interviewed. An unmanned aerial vehicle (UAV or drone) was used to measure the distance between the disaster-affected area and the surveying site from the air. This survey technique was used as bank instability rendered it dangerous to approach the high-risk riverbank at close proximity. The UAV enabled estimation of the height of the failured bank, close visualisation of the soil layer, and identification of the failure movement pattern. The drone was also used to conduct real-time observations and generate data in ArcGIS 10.3 to identify the affected area and damaged properties. Furthermore, the drone captured real-time movement of the bank and houses collapsing, which was important for recording the disaster scenario chronology.

A fast-forward structural interview was conducted with 10 randomly-chosen respondents from 47 adult victims. The 10 respondents were direct victims as their property was destroyed in the riverbank failure. The Krejcie and Morgan theory states that a population of no more than 50 people is suitable for research; therefore, it was appropriate to randomly select five to ten people from the chosen population (Krejcie & Morgan 1970). During the interview, all relevant information, such as the event chronology, psychological effects on the victims, future planning following the disaster, and the consequences of the failure (which destroyed local business premises) on the victims' income was collected. Study had done FGD in two hours with the selected respondents. The respondents had shared their experiences and suggest the solution and some advices to the community who living along the riverbank. Three field surveys were conducted: in the immediate aftermath of the disaster, during the disaster investigation by the authorities, and at the start of the riverbank stabilisation project. The interview data were analysed using the thematic analysis technique while the UAV data were analysed using the buffering technique in ArcGIS software.

RESEARCH FINDINGS

THE AFFECTED AREA OF THE RIVERBANK FAILURE

The DID identified risk zones after the riverbank failure to aid victim relocation and investigation work. According to DID secondary data, the red zone extended approximately 50 m from the riverbank (Department of Irrigation and Drainage 2021). Study had defined the parameters for the red, yellow and green zone which represent the risk zone of the affected area. The red zone in range of 50 meter from the bank. Besides, orange zone is 51-100m, yellow zone is 101-150 m and for green zone is 151-200m onwards. The DID conducted a risk assessment of the riverbank stability before determining the risk zones so that the inhabitants could implement precautions and decide whether they should relocate to a safer location.

A ground study was conducted based on the risk zones to determine the number of buildings affected by the disaster. The red zone contained a total of 21 houses and premises of which 11 failures due to the unstable riverbank. The orange zone contained 23 houses and businesses. Three orange zone houses were unsuitable for occupation and the residents were required to relocate immediately to a safer location. The remaining houses and premises in the orange zone could remain until the authorities issued another announcement as the authorities were required to conduct a thorough investigation to determine whether the risk zone should be expanded or maintained considering the current situation. The 33 houses and businesses in the yellow zone were unaffected by the disaster. The green zone contained 30 houses and businesses that the authorities maintained and declared a safe zone.

The UAV data demonstrated that the soil movement persisted from day 1 until day 23 when the movement stopped and no new building cracks were detected. During the early stage of the disaster (riverbank collapsed 1-5 meters), the bank movement was relatively swift and could or even be felt when the researchers were in the high-risk zone (see Figure 3).

FIGURE 3. Affected Area

The ArcGIS was used to perform a buffer analysis of the research location to identify the zone in the real situation with the DID-established zone range. Figure 4 depicts the 11 houses affected in the red zone. The investigation discovered that a car had collided with the unstable riverbank.

FIGURE 4. Failured Houses and Sheer Pile

In the red zone, three huge riverbank failures occurred within the 23 days. Consequently, the DID encouraged villagers in the red zone to relocate as soon as possible as the quick soil movement might have endangered them. The local administration assisted all impacted persons in finding temporary housing until the federal government approved compensation. Of the 23 dwellings in the orange zone, only five were harmed by the riverbank failure. The afflicted homes had to be demolished while the residents had to relocate to a safer location.

Movement was identified by monitoring cracking on building walls (see Figure 5). According to DID records, the movement continued each day and numerous fissures developed on the walls or the road nearby. Nevertheless, the damage was not as severe as that in the red zone where the buildings had completely failure. The aforementioned cracks expanded daily until no movement was detected on day 23. The DID representative was concerned if the movement would continue or if there would be any future changes as it could not be confirmed whether the soil structure was sufficiently strong to support construction.

FIGURE 5. Measurement of a Cracked Wall

THE COMMUNITY AND SOCIO-ECONOMIC CONSEQUENCES

Any disaster may bring consequences to the community and socio-economics (See Too 2018). Respondent mention that this riverbank failure incident caused lots of negative impacts to the local socio-economic since the exact place was a market which is Pasar Munduk and residential area. This market so called is a trade center of the Pasir Mas community. Kg. Pohon Celagi also surround by many services center such as post office, veterinary clinic and banks. According to the residents, they usually will get their daily needs from the nearest market and the market was there since 5-6 decades ago. Hence, this disaster not only destroyed their living place, it also destroyed the historical place and identity of the Pasir Mas.

In Kg. Pohon Celagi, along the riverbank in the village were several residences and businesses that had operated for 50 years. Most were modest businesses, such as food and beverages, groceries, watches, and spectacles. These businesses were not prospering but created sufficient income to support the villagers' daily expenditures. The survey determined that the inhabitants of the research area shared a relatively close relationship as they had lived in the same neighbourhood for many years.

The riverbank failure negatively affected the surrounding area, specifically the town operations, which became less effective due to the large crowd (relocated villages) and limited-premises operation due to stabilisation work that necessitated the closure of major roads to ensure project completion without inconveniencing the public. The disaster negatively affected the local community and the socio-economic status of the town.

According to Watakabe et al. (2012), riverbank failure at Rajang River also caused many longhouses have been lost due to the erosion and the villagers were losing their shelter and force to relocate to another places. Same case to the Kg. Pohon Celagi riverbank failure, the villagers were unprepared for the suddenness of the riverbank failure, which impacted their lives significantly. The affected villagers were required to find other places to live, which might have led to financial difficulties. This is because the victims have to spend an amount of money to buy and build a house before compensation given by the government. According to respondent during the interview, the compensation will not give to whom build house at river reserve area. Even though, while the victims received compensation from the local government, the procedure proved tedious. Dato' Ahmad said state government provided a short-term aid center for the victims during the disaster occur. The short-term aid is an evacuation center for the affected victims. Subsequently, the victims planned to seek compensation from the federal government represented by the Ministry of Natural Resources, Environmental and Climate Change (NRECC). Applying for compensation was a lengthy procedure that involved the completion and submission of all house or premise documents. The survey respondents indicated their gratitude for the assistance and compensation but also stated that the expenditure for replacing their furniture and installing home security systems imposed financial burdens on them.

DISCUSSION

Riverbank failures are common natural disasters, specifically in large rivers where the hydrological process is more active and may lead to bank erosion. The Kelantan River is classified as a large river and the watershed geomorphology system is extremely unstable due to the high-water flow rate. Furthermore, bank failure had occurred along the river due to human activity such as sand mining, business, agriculture and courier services. The main Kelantan River activity is sand mining, which supplies sand for construction. Sand mining undoubtedly impacted the river morphological system and increased riverbank instability. According to the Department of Irrigation and Drainage, 2021, the major reason for this disaster was the curved river morphology and rapid water flow, specifically during heavy rains. Hence, the concrete sheer pile at the research area failured due to the morphological impact.

According to Elena et al. (2011), persons who live near riverbanks are at high risk of disasters related to stream interaction. Such a disaster has several implications, including money and property loss, trauma, and death. This research identified four zones established by the DID: red, orange, yellow, and green, which each spanned 50-m distances. Each zone featured different effects and damage rates. For example, the red zone had a high damage rate compared to the other zones as the unstable bank failured drastically and became a deep slope. The rapid movement also caused the failure of 11 houses. Most of the riverbank failure downstream may have caused buildings to failure and endangered the people living along the riverbank.

A riverbank failure causes a wide-ranging impact on the environment and human activity (Tanmoy & Biplab, 2020). When an environmental disaster affects daily community life, the surrounding socio-economic environment declines, as the socio-economic potential of the area is driven by the community. Furthermore, the inconvenience caused by rebuilding the disaster area will cause socio-economic weakening. During the Kelantan River disaster, many communities in the affected area were unaware of the occurrence and unprepared to address the situation, which caused significant losses. This research demonstrated that the victims lost money and their homes and that their daily routines were disrupted.

Following the disaster, the government provided a relief scheme to the victims in alleviating their financial difficulties. The federal government allocated RM62 million for disaster management, which included riverbank reconstruction, compensation, and repair of the DID water pump. The compensation amount will ensure that the disaster area can recover and become more resilient against erosion or other causes that may cause future riverbank failure.

CONCLUSION

This study identified the zones in the riverbank failure disaster area with each featuring a different damage level. The affected community was required to relocate to a safe location and be compensated based on their total losses. Several effects arose from the riverbank failure. According to the District and Land Office of Pasir Mas (2023), the population in this district is 187,706 people and many people in this district is running their own business. Due to the high population density and number of businesses operating (43% people have their own business) in the disaster region, the disaster caused negative primary consequences on the community and socio-economics. Fortunately, the disaster caused no injuries or deaths.

The federal governments allocated RM62 million for riverbank reconstruction and stabilisation work (Ministry of Natural Resources, Environmental and Climate Change, 2021). Moreover, this amount also included compensation and victim relief as well. To ensure that community well-being is enhanced, the risk and threat of riverbank failure can be reduced with high awareness and preparation such as apply underground soil movement detection system and educate the community regarding the way to escape from the same disaster. Hopefully, all stakeholders, including the government, public sector, community, and non-governmental organisations will have high awareness of such disasters.

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See Too Kay Leng
Faculty Social Science and Humanities,
Universiti Kebangsaan Malaysia
Malaysia
Email: cayleenst@gmail.com

Mokhtar bin Jaafar
Faculty Social Science and Humanities,
Universiti Kebangsaan Malaysi
Malaysia
Email: m_jaafar@ukm.edu.my

Frankie Marcus Ata (Corresponding author)
Faculty Social Science and Humanities,
Universiti Kebangsaan Malaysia
Malaysia
Email: frankie@ukm.edu.my

Mohd Ridhuan bin Mohd Jamil
Faculty of Human Development,
Universiti Pendidikan Sultan Idris
Malaysia.
Email: mridhuan@fpm.upsi.edu.my