The Capability of Spatial Analysis in Planning the Accessibility for Hazard Community from Debris-Flow Events

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Debris flow is a destructive disaster causing tragic loss and damages to vulnerable people and their properties in many regions around the world. According an impact of this disaster, hazard areas are submerged in mud and debris causing enormous difficulties to all relevant organisations and affected people to access over the hazard community. Although an inaccessibility is one of the major problems considered to be solved in an urgent stage, the lack of a comprehensive study in activities of involved people through time line since the disaster occurrence causes a difficulty to plan the feasible solution to overcome those problems effectively.

Therefore, this paper presents the existing knowledge in several activities related to accessibilities in hazard areas. Additionally, the initial findings derived from interviews conducted as a part of a doctoral research are determined showing real activities related to accessibilities in a study area of Thailand where was attacked by a major debris-flow event in 2001. Regarding the explored acitivities, this study aims to introduce a potential solution to overcome the inaccessibility problems in hazard areas by applying spatial analysis techniques. This solution presents a new method of an optimum balance between the explored problems from the interviews of affected people and the practices conducted by the local government to solve the inaccessibility in the hazard area. Some suggestions are addressed at the end of the paper to propose some additional practices with some considered factors for the spatial database design.

Key Words : *Debris flow, Spatial analysis*

1. INTRODUCTION

Basically, the forms of habitats are inclusive with economically productive, socially just, politically participatory, ecologically sustainable, and culturally vibrant[1)]. Regarding some ventures, residents are displaced to other places either voluntarily or involuntarily, i.e. development projects, conflict and war, and natural disasters[2)]. Considering the number of displaced people, natural disaster-induced displacement has been claimed as a major cause displacing people more than development projects or wars[3)]. The number of natural disasters has increased dramatically throughout the world in these present days. It is reported that natural disasters have increased from 200 to more than 400 events over the past two decades[4)]. Surprisingly, natural disasters have increased over 400 % within two decades during 1960s-1980s with three to four times of killed people and 40 times of affected people higher in developing countries than developed ones[5)]. Additionally, this tendency has never been declined in the developing region, particularly in Asian countries[6)]. Considering a sharp increase of natural disaster types, hydrological disaster, i.e. floods and wet-mass movement, are the most frequent incidents causing displacements over Asian countries[7)].

Debris flows and landslides are destructive wet-mass movement severely destroying all attacked communities. This surging flow of water and debris runs rapidly in steep channel to catchment areas and potentially attack all obstacles[8]. Focusing on this destructive disaster in Asian countries, debris flows have occurred frequently in many mountainous areas of Thailand in these decades. As the recorded number of landslide and debris-flow occurrences from 1988-2007, these disasters have occurred approximately 90 times and subjected to increase throughout the country[9]. Those incidents were announced as natural disasters, which requested internal and external assistance[10]. For this reason, many authorities and stakeholders are assigned by the government to provide any urgent helps to mitigate the suffering from affected people. The destructive condition of the hazard area is a major barrier for accessing to provide those helps in emergency phase, eventhough, the policy and strategy have been planned and implemented by local government so far. This circumstance is necessary to study further to explore an effective method to overcome the problems in this stage.

Thus, this study attempts to propose an effective solution of an optimum balance between the top-down policy organised by the local government and the explored problems from affected people regarding debris-flow event in Nam Ko Yai catchment in Thailand. Initially, this study commences with studying the top-down policy implemented in post debris-flow event in 2001 and exploring problems from affected people's experiences associated with the accessibility over the hazard community. The complexity of the problems associated with the accessibility are revealed by the in-depth perception from interviews integrated with observation and documentary analysis. As this problematic based study, a period of emergency phase of resettlement programmes is reclassified to define the post-disaster management associated with accessibility heirachially. The expected outcome of this study presents potential methods reccommended in the optimum balance for examining in spatial analysis in GIS. This study presents the acquired layer maps based which are applicably prepared for a fast response in overcoming the inaccessibility in other hazard communities at local scale with the same context.

2. LITATURE REVIEW

(1) Activities after disaster occurrence

After the disaster occurrence, affected people in hazard area have to encounter with chaos, trauma and suffering. Scudder (2005) described that activities after the disaster event consist of recruitment; identify the exposed victims, transition; construct the resettlement sites and removing processes, potential development; improve re-settlers' living standard by community and economic development, and hand over; applicably hand over and incorporate through the next generation[11]. Likewise, Corsellis and Vitale (2005) clearly defined some crucial activities organised by the local government since the emergency starts as followed[12]:

a) Update information for all stakeholders
b) Identify Ethnic, religious, social background
c) Provide specific assistance for vulnerable hazard area
d) Increase income opportunities
e) Supply availability and capacity of sheltering area
f) Register displaced people
g) Provide emergency health-care treatment
h) Establish supplementary feeding centres

Thus, it can be summarised from those previous works that there are four main categories such as: *i) economic development, ii) sustainable livelihoods, iii) infrastructure and hazardous area improvement, and iv) cultural identity,* essential to be carefully improved after the disaster occurrence by involving authorities based on the *updated information of affected people.*

However, it is difficult to define the exact period of emergency phase after the disaster occurrence. The first stage since disaster occurrence is generally addressed as a stage before the displacement[13]. In this stage, evacuation centre is normally established to collect affected people and to provide space for assistances. Regarding the framework of the United Nations, the emergency shelters and evacuation centres have to be established to provide the emergency helps and also to maintain the rights of displaced people[14-16]. The framework of operational policy outlines the significance of the emergency state and subsequent programmes in which to ensure fair and adequate compensation of affected people[17].

(2) Accessibility, one of the challenges in emergency stage

Accessibility is an early concern of involving authorities who access into the destructive hazard-area to provide the emergency help to suffered people. However, there is little comprehensive study about accessibility management in hazard area. The lack of a study regarding accessibility causes a major delay in transportation in post-disaster management. On one side, displaced people have to travel to emergency centre and collecting point regularly to obtain some helps and services. On the other hand, massive assistances also access to the hazard community to provide some helps to those affected people. Therefore, roads are typically prepared to facilitate those authorities including the displaced people. Based on a guildline of restoring and constructing roads in hazard area, it is described in a Handbook for emergencies by the UNHCR with various interests and schemes[14]. Considering the details in the handbook regarding road, it is suggested that roads must be "all-weather road" above flood levels, which provides year-round access. Short access roads to connect the main road with the site can be constructed as part of the camp development. It is also recommended that road construction would follow contour lines in order to reduce erosion, preserve topsoil, and avoid the creation of dangerous gullies. In case of a significant amount of vehicle traffic on the site, pathway must be separated for specific pedestrian traffic.

(3) Roles of spatial analysis in analysing accessibility in emergency stage

Spatial analysis, an application integrated with Geographic Information System (GIS), has been employed to analyse the spatial problems in emergency stage in many studies. Generally, location of evacuation centre has to be identified in safe place with the installed infrastructure and facilities. It is obvious that spatial analysis has been applied to determine the locations suitable to construct the sheltering site. For instance, a study of Gall (2004) presented an efficient modelling to analyse the shelter sites and their accessibilities[18]. Applying this technique, the vulnerable communities in hazard area can be exposed and determined the suitability of additional emergency shelter sites by weighting technique based on Landsat images. Some basic functions of spatial analysis were applied to present the destructive areas from a topical hurricane disaster in India[19]. Additionally, Schmidt-Soltau and Brockington (2007) used the secondary data from collected database available in GIS to analyse the considering number of sites to justify the relocation decision[20].

Accessibility is a significant parameter applicably measured by using spatial analysis. The application of spatial analysis can solve several problems associated with the accessibility of spatial aspects from the basic functions and extension functions in GIS programme. Focusing on a study by Corsellis and Vitale (2005), they concluded that displaced people frequently access to acquire the basic needs, such as[12]:

- Access to land for settlement and agriculture;
- Access to water, fuel wood, and construction material;
- Access to security
- Access to food aid in emergency phase
- Access to community service, such as health centres and schools.

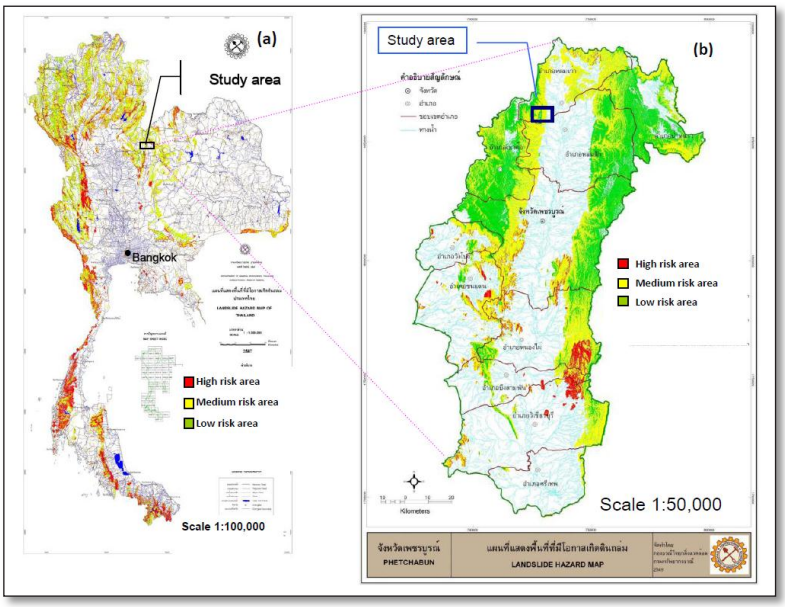
3. STUDY DESIGN

Regarding this study attempts to explore the in-depth information from those respondents in hazard community about accessibility, a case study strategy is the most preferred for this study. Typically, case studies are designed into four types such as; single-case (holistic) designs, single-case (embedded) designs, multiple-case (holistic) designs, and multiple-case (embedded) designs[21]. This is to say that sub-categories in case-study strategy consist of single-case studies and multiple-case studies. Single-case studies consider a single unit of analysis, such as; a critical case which is well formulated a theory, an extreme case or unique case which is worth documenting and analysing, a representative or typical case, a revelatory case which an investigator has an opportunity to observe a phenomenon, and a longitudinal case which shows how certain conditions change over time [21].

Initiately, this study attempts to explore the problems associated with accessibility and explain the relationships between the explored problems and the applied policy. This study takes a single-case (embedded cases) design to analyse the perception of respondents regarding the accessibility over hazard area in emergency period after the disaster event. One of the principles for data collection is the opportunity to go back to the raw data by investigating the chain of evidence[21]. The case study strategy includes several collection techniques such as interview, observation, documentary analysis and questionnaire[22]. This study takes the interview (semi-structured interview), observation, and documentary analysis as the techniques which are

triangulated to ensure the reliability and validity of the collected data.

According the research methodology, the study area presents a representative case of the displacement from those debris-flow events in Thailand. This study area played a significant role as the first place employed an official resettlement programmes in Thailand. Initially, temporary houses were officially built up to achieve the resettlement programme of this study area. For the unique and original case of this study area, this study considers a single case study based on these basis. Twelve affected people and two authorities involved with the 2001 debris-flow event in Nam Ko Yai catchment area in a Northern province of Thailand (Fig. 1) were representatively interviewed regarding the accessibility problems.

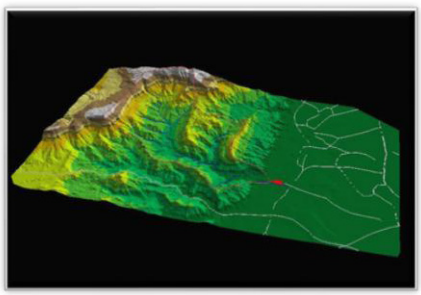


Notes: (a) Landslide-hazard map on the regional scale
(b) Landslide-hazard map on the medium scale

Fig.1 Debris-flow and lanslide-hazard map of Thailand
(Source; http://www.dmr.go.th/geohazard/landslide/landslide_hazard.htm)

Considering the database preparation, some spatial features have been analysed and performed in digital map layers based on LiDAR data and airborne imagery as presented in Fig 2. Basically, the map layers for analysing the accessibility over hazard area requires the preparation as:

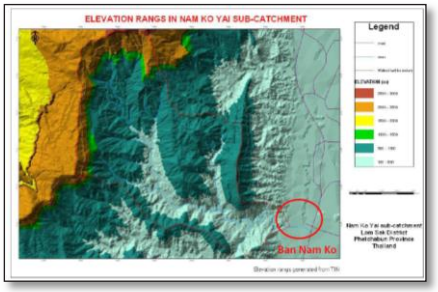
- Elevation map
- Road map
- House map
- Administrative and community boundary map
- River map
- Public spae and service map



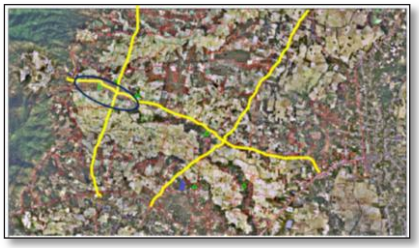
3D model of study area

Note = hazard community

= road



Elevation of the hazard community (Ban Nam Ko), based on LiDAR data



Main roads connected to the hazard community

Note:

= main roads = hazard area

= secondary roads

Hazard area and evacuation centre

= Hazard community

= Evacuation centre

Fig.2 Database prepared for determining the accessibility over hazard community in spatial analysis

4. RESULTS

(1)Defined emergency period

An emergency period has been declared differently from place to place after the disaster occurence. It can be claimed that an emergency stage is defined since the disaster occurrence until displaced people are comfortably installed into a provided living place where essentially basic infrastructure and facilities installed[12-13, 15, 23-24]. According the collected information from the semi-structured interviews, activities asscociated with accessibility in emergency stage can be listed through time in the Table 1.

Table 1 Activities associated with accessibilities in emergency stage through time

Activities	Places		Period of Time (Start from)	Operator(s)
	From	To		
1. Distribution				
i) Injured people	• Disastrous area	• Hospitals	• Urgent-24 hrs	• Rescue staff & Military
ii) Dead people	• Disastrous area	• Temples	• Urgent-7 days	• Rescue staff & Military
iii) Donation items	• Outside community	• Collecting centre	• Urgent-30 days	• Donors, Royal Family, and Charities
2. Debris removal				
i) Debris on road networks	• Disastrous area	• Outside community	• Urgent-3 days	• Military & Local government
ii) Debris on Residential/ agricultural lands	• Disastrous area	• Along main roads	• 4^{th} – 15^{th} days	• Owners, Neighbours, Relatives
3. Reconstruction				
i) Houses				
• Entirely damage	• Residential areas	• Evacuation centre	• 1-30 days	• Owners, Military, Hired labours
• Partly damage	• Residential areas	• Evacuation centre, Relative's homes, Agricultural lands	• 1^{st} – 7^{th} days	• Owners, Military, Hired labours
• Not damage	• Residential areas	• Evacuation centre	• 1^{st} – 5^{th} days	• Owners, Neighbours, Relatives
ii) Public infrastructure	• Inside/outside community	• Public infrastructure areas	• 2^{nd} – 15^{th} days	• Local government, Hired labours
iii) Social service buildings	• Inside/outside community	• Social service areas	• 15^{th} – 30^{th} days	• Local government, Hired labours

Regarding the analysed information shown in the Table 1, the emergency phase of debris-flow event in case of Nam Ko Yai catchment takes the minimum 30 days to restore houses and public services properly including to relocate displaced people into the provided temporary houses. Those major acitivities can be prioritised by: a)

considering the urgent requirements and necessities from distributing injured people to hospitals, b) removing dead people from submerged land to temples for funeral ceremony, c) distributing donation items to suffered people, reconstructing houses, and d) restoring public infrastructure and social service buildings. In particular, the first three days are the most chaotic period due to roads in hazard area have been submerged in mud and debris. Main roads connected to outside communities are the first priorty to be restored in order to serve all kinds of transportaion.

(2)Forms of accessibility

Generally, affected people access over the hazard community in emergency stage by walking due to almost of them lost their vehicles from torrential debris-flow and flood. Local government are in charge to restore all essential main roads for transportation. Regarding the scope of accessibility of people since the disaster occurrence from a study of Corsellis and Vitale (2005), it can be applied those forms of accessibility to the study area as[12]:

a) Access to land for settlement and agriculture;

Displaced people had to travel to evacuation centre and stay there until they ensured that the severe situation was controlable. In this case, the evacuation centre was crowded with affected people in the first five days. Generally, there were three kinds of affected people displaced to the evacuation centre in emergency stage such as: i) displaced people whose houses were entirely destroyed, ii) displaced people whose houses were partly destroyed, and iii) displaced people whose houses were not destroyed. Displaced people whose houses were entirely destroyed normally stayed longer in evacuation centre than other groups. Displaced people whose houses were partly destroyed normally stayed in evacuation centre within a week and travelled widely to restore their homes. Displaced people whose houses were not detroyed normally stayed in evacuation centre for few nights to ensure that the situation was in control then moved back to their homes to remove debris, mud, and stain. In this case, people rarely accessed to restore or cultivated on their farm lands due to the difficulty in transportation in this emergency phase. In addition, people merely relied on donation items to survive in this period.

b) Access to water, fuel wood, and construction material;

Water and fuel wood were provided by local government in the emergency phase. These resources were sufficient and provided in the evacuation centre. Therefore, the access to those resources did not play any significant role in this case. Reconstruction task is the third priority after removing debris and mud from the submerged lands. This mission had not only been done by affected people and their families, but also by the assistance from neighbours, relatives, and hired labours. Local government was in charge to restore all public infrastructure, facilities, and social service buildings. For this reason, there were a number of vehicles and construction machinery running through the destructive lands to convey construction material and labours.

c) Access to security;

Security service was set by police and volunteers who were in charge in investigating around the evacuation centres. However, displaced people from partly damaged houses and non damaged houses were not fully protected by the police and volunteers due to the broad residential area. These groups of affected people displaced to evacuation centre and stayed there at least few nights due to the security reason. They were terrified by the possible disaster occurrence. For this reason, displaced people randomly walked from their lands to evacuation centre in order to access to security

d) Access to food aid in emergency phase;

Affected people accessed to feeding centre for food and donation items in emergency phase. This accessibility showed a very important pattern of travelling throughout hazard community. As dependent status, affected people had to rely on donation foods. In this case, feeding centre was established in evacuation centre. Displaced people had accessed to this feeding centre by using main roads in the first few weeks and some secondary roads afterwards. Affected people had to travel from their homes to the feeding centre several times a day to collect some donation items from donors, royal family, and charities.

e) Access to community service, such as health centres and schools;

There were several community services serving affected people at evacuation centre such as mobile health units, mobile toilet units, etc. In case of severe accident from this event, affected people were distributed to the nearest district hospitals outside the hazard community. Focusing on the local school in hazard community, students returned to their classes after the emergency phase due to the cancelled classes. In the meantime of

emergency phase, all class-rooms had been applied as temporary living space, storage rooms, and administrative area response to a large number of people and urgent requirements.

(3)Challenges from bottom-up reflection associated with accessibility over hazard area

a) Submerged roads

As a result of debris-flow event, some parts of the roads had been covered by debris and submerged in mud. This circumstance blocked all routes in hazard area.

b) Stuck vehicles in mud

Debris and mud had been removed by machines using the main road, however, some machines were stuck on the soft surface of shoulders covered with mud. This circumstance delayed the debris and mud removal due to the machines had blocked some routes in hazard area. In order to lift the machines from sinking in the submerged land, some massive vehicles were required for this mission which increased traffic and chaos over hazard and adjacent areas.

c) Insufficient road channel

Accordingly, removing debris and mud covered on the main roads were the first priority in accessibility manners. Main roads were restored for urgent mission to provide the accessibility into and outside the hazard community. These main roads were intensively used by involved helpers and affected people travelling to the evacuation and feeding centres in particular the first week after the disaster occurrence. This mixed implementation between rapid vehicles and passengers reduced the channel of urgent transportantion, delayed the travelling time for any emergency tasks, and possibly caused any subsequent accident.

d) Cluster emergency service centres

Considering in this case, evacuation centres were established by applying a social service buildings, which contained several units in each area such as: feeding centre, collecting point, mobile health unit, communication centre, and distribution centre. Furthermore, the evacuation centres have their own original functions as a temple and a school. As a typical function of a temple, the evacuation centre were used as a funeral ceremony affair and also applied as the sheltering area for affected people. This mixed used of typical and adaptive functions caused chaotic situation within the centre in emergency phase. Furthermore, affected people, volunteers, locoal government, stakeholders, etc were heading to these two centres in the mean time. On the other hand, although the distance from the evacuation centres to the most remote hazard area is less than five kilometres, affected people needed to walked through the submerged land from their homes to these centres several times a day to receive some food and donation items. This caused people to encounter with the difficulty from the accessibility and risked their lives to death.

(4)Role of government and organisations in top-down policy regarding accessibility context

Local government and authorised organisations had been assigned by the government to mitigate and help those suffered people in this hazard area. Focusin on the accessibility throughout the hazard community, the local government and authorities were in charge to get involved with many missions such as:

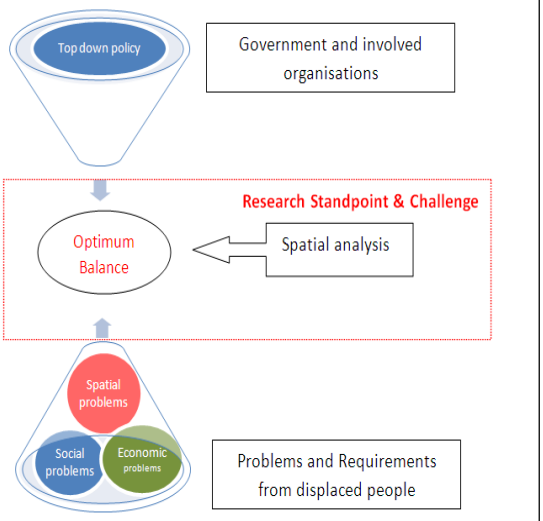
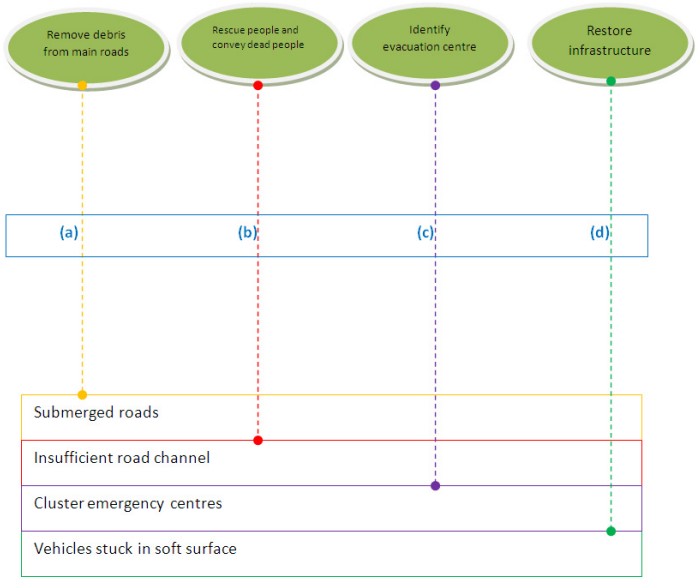
a) Remove debris and mud from the main roads
b) Access to rescue injured people and convey dead people to communal service places
c) Identify evacuation and feeding centre
d) Restore infrastructure and facilities

(5)Optimum balance between top-down policy and explored problems from bottom-up approach

As a result of this study, an optimum balance between the top-down policy and problems explored from the bottom-up approach is proposed for a further analysis in spatial analysis in GIS platform. Following the framework of the study in Table 2, an applied framework is designed to present an optimum balance between the missions organised by the local government and the real statement of problems from interviewing affected people in the study area. Missions organised by local government associated with accessibility were to remove debris and mud from main roads, to rescue injured people to hospital including convey dead people to temples for furthering funeral ceremony, to identify the evacuation and feeding centre with essential facilities, to restore the public infrastructure in hazard community. It is obvious that affected people had faced with some trouble associated with accessibility through the hazard community in emergency phase such as: inaccessibility due to submerged roads and lands, mixed usage between roads for transportation and walking

paths causes insufficient road channel and traffic congestion, difficult to access due to the distance from homes to evacuation and feeding centres, trouble traffic congestion around these centres due to the provisional cluster-centres, and many vehicles accessing to the hazard community were stuck in parking area due to the soft surface of the parking area.

Table 2 Framework of the study and applied framework with explored results

Framework of the study	Applied framework with explored results
	

Note: (a), (b), (c), and (d) are considered factors and methods in spatial analysis of the optimum balance between the top-down policy and problems explored from the bottom-up approach associated with the accessibility

Considering the basic and prepared data used in spatial analysis in this purpose, all routes in hazard community is the most important data. It is also essential to prepare a contour-line map displaying elevation over the community. All public infrastructure, facilities, social service buildings, and available open areas have to be identified on a public space map. All applicable functions of spatial analysis to perform the optimum balances between the missions organised by the local government and the real statement of problems from affected people is proposed as below:

a) Optimum balance (the (a) challenge in Table2)) between: a mission to remove the debris and mud from the main road, and the trouble problems from submered roads must consider;
- A shortest path between the main roads to a debris- and mud-disposal area.

b) Optimum balance (the (b) challenge in Table2)) between: a mission to access in/out the hazard community to rescue injured people to hospitals & convey dead people to temples, and the traffic congestion blocked this urgent mission due to the mixed usage between walking paths and main roads must consider;
- A network analysis connected to other community routes to the nearest hospitals and temples
- Buffering main roads for avoiding the mixed usage between walking paths and providing channels for any emergency transportation

c) Optimum balance (the (c) challenge in Table2)) between: a mission to identify evacuation and feeding centres, and problem to access the centre must consider;
- Location analysis to identify evacuation centre in safe place
- Identify the shortest paths of all secondary routes for transportation to evacuation centres

d) Optimum balance (the (d) challenge in Table2)) between: a mission to restore public infrastructure-facilities- and social-service buildings, and stuck vehicles in soft surface parking area must consider
- Locational analysis to identify potential parking areas
- Network analysis to display the connection routes of the secondary and main roads around potential parking areas

5. SUGGESTION

Considering all challenges from the explored results, there are some suggestion regarding the locations of evacuation, feeding centres and locations for parking area. According the in-depth perception of respondents, there are some important context showing that affected people had been suffered from travelling between their homes and evacuation centres to collect donation items and food several times a day. The difficulty in accessing those centres impacted to those affected people's health spontaneously. The most trouble situation from these difficulties caused the death to some people from tetanus due to widely roaming onto destructive areas where covered by debris.

Predominantly, this study alternatively suggests multiple collecting points located in safe places where closed to villagers who also relied on the donation items due to a broad destructive area over the entire community. It would be suggested that the collecting point would be located separately from the evacuation centre to avoid the crowded circumstance in the centre. This collecting point can be used as feeding centre, registration centre, distribution centre, broadcasting information centre, including mobile health and mental support unit. Some factors must be considered in the database design in the GIS to analyse the best site of these proposed multiple collecting points in communities as:

a) Located in high & dry land; considered from contour map
b) Apply the available social service building with sufficient space; considered from public space map
c) Closed to residential community; considered the density of houses on the house map
d) Located within administrative boundary; considered from administrative or community boundary map
e) Accessible through by using secondary roads which connected to the main roads; considered from road map

Fig.3 Database required for best site of multiple collecting points

Additionally, a large number of donors accessing to the hazard area can also cause serious traffic congestion. For this reason, parking areas with local transportation driven by local drivers from parking areas to collecting centres would be recommended to shuttle donors and donation items directly to the collecting points. Therefore, this study would suggest those donors consider park & ride mean to access through the hazard community. This service can reduce the number of traffic running and parking around collecting centre which will be able to cause a serious congestion. Some factors must be determined to select the best location for a parking area such as:

a) Hard surface land far from the impact of disaster; considered from contour and land parcel map
b) Connected between main road(s) and secondary road(s); considered from route map
c) Located on available space; considered from public space map
d) Away from hazard area; considered from distance to the destructive area

Fig.4 Database design for best site of parking area

In conclusion, it would be suggested that main roads would be used for only distribution purposes within the first 15 days to distribute injured people to the hospitals, distribute dead people to temples, distribute donation items to collection points, and convey the removed debris from hazard area, in order to avoid the traffic congestion problem in hazard area. The secondary roads, short cut, and walk paths linked to the collecting points would be restored to reduce the distance in which affected people enable to walk conveniently to the collecting points several times a day.

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