THESIS

DETERMINING TSUNAMI EVACUATION BUILDING LOCATION AND EVACUATION ROUTES BASED ON POPULATION DYNAMIC AND HUMAN BEHAVIOR IN DISASTER EVACUATION IN PACITAN SUB-DISTRICT AREA

Thesis submitted to the Double Degree M.Sc. Programme, Gadjah Mada University and Faculty of Geo-Information Science and Earth Observation, University of Twente in partial fulfillment of the requirement for the degree of Master of Science in Geo-Information for Spatial Planning and Risk Management

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Has been approved in Yogyakarta
April 2017

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DISCLAIMER

ABSTRACT

Pacitan sub-ditrict is located in south part of East Java, facing Eurasian and Australian Plate subduction zone and prone to tsunami hazard. Pacitan government proposed 20 formula that means when 20 second earthquake occure, people only have 20 minute time to evacuate with 20 meter as minimum safe elevation to escape for education and socialization systems toward people. 12 horizontal evacuation location have been determined in elevated area surrounding city center. Tsunami simulations using sirens as early warning system also have been implemented to make people familiar with the evacuation system. However, the panic situation during disaster that occur suddenly make people can not think clearly to evacuate, especially for tourist as stranger that do not know anything about the system in that area. Moreover, the main tourism attraction in this area is Teleng Ria beach with 427,262 number of local visitors in 2015. By considering human behavior in disaster evacuation, this research presents the determination of propose tsunami shelter building location and evacuation route based on tourist perspective in disaster evacuation.

Cost weighted distance (CWD) was applied to define catchment area (basin) in each shelter location based on landuse, slope, and average human speed as input data. The catchment provide information about evacuation time in each pixel size area towards shelter location. Average human speed in this research is 0.936 m/s based on human walking speed test result that was conducted in Pancer Door beach.

The number of population in study area was modelled and distributed in tesellation form by considering population estimation in house and public facility in day and night scenario also considering with and without tourist. The number of population in each tesellation in different scenario and the calculation of shelter capacity were used to calculate the shelter ability to accomodate people. Additional shelter that are needed was calculated in each catchment area. Based on the existing 11 shelter location in study area, there are 3 shelter location (ID V3, V5 and V6) that need to build additional shelter building because there are no option to define additional shelter building based on existing multi storeys public facility. 3 from 11 existing shelter (ID H1, H4 and V2) are enough to accomodate people in catchment area, while the rest need additional shelter by using the existing multi storeys public facility.

Evacuation route was developed in each catchment area based on tesellation point, shelter destination and road network by using Network Analysis method in ArcGIS. Finding the closest facility was choosed to define shorter route by considering 20 minutes time impedance in each shelter.

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Lufti Gita Iriani

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ABBREVIATONS

ADPC	Asian Disaster Preparadness Centre
BMKG	Badan Meteorologi Klimatologi dan Geofisika (Meteorology Climatology and Geophysical Agency)
BNPB	Badan Nasional Penanggulangan Bencana (Disaster Management National Agency)
BPS	Badan Pusat Statistik (Central Bureau of Statistics)
CWD	Cost Weighted Distance
EOC	Emergency Operation Centres
ETA	Estimation of Time Arrival
FEMA	Federal Emergency Management Agency
GITEWS	German-Indonesian Tsunami Early Warning System
NGO	Non Government Organization
TEBC	Tsunami Evacuation Building Capacity
TEW	Tsunami Early Warning

CHAPTER 1. INTRODUCTION

1.1 BACKGROUND

A tsunami is a natural disaster showing as a destructive wave because of a disturbance in the sea. Joseph (2011) divided the tsunami generation into 5 types, namely: seismic, landslides (submarine or surface), volcanic, atmospheric disturbances, and asteroid impacts. Approximately 82% of the tsunami events are generated by seismic activity, like tectonic plate movements (earthquake) that causes vertical movement of the ocean floor.

A tsunami hazard zonation can be determined by using models such as the MOST model, SELFE (Bryant, 2014b), TsunAWI (Behrens, 2008) and TUNAMI model (Mardiatno, 2008 ; Bryant, 2014 ; Sutikno & Murakami, 2015). The modelling result show the inundation zonation distribution in that area, including inundation extent, tsunami wave height, etc. The area outside inundation zone can be determined as safety zones which is possible to serve as evacuation sites.

There are two possibility in defining evacuation sites, horizontal and vertical evacuation. Horizontal evacuation is suitable for hilly area where it is possible for the people to reach higher places before the tsunami reaches the coast. On the other hand, vertical evacuation is suitable to be applied on flat terrain, that is not possible to reach higher terrain, and people need to escape to the multi-storey building to safe their life. The decision of using vertical or horizontal evacuation will depend on area characteristics and the estimation of the tsunami arrival time. Additional evacuation buildings are needed when the existing capacity is not enough to accommodate the people. The FEMA (2009) determined vertical evacuation types such as existing or engineered high ground, parking garages, community facilities (community centers, recreational facilities, sport complex, libraries, museums, police station and or fire stations), commercial buildings (hotel, condominiums, restaurant), and school facilities. Furthermore, Budiarjo (2006) also defined vertical evacuation buildings criteria based on the existing building after tsunami in Aceh, Indonesia i.e. should be located at a distance more than 200 m from the shore, well planned and designed, good quality construction and building floor reserved for evacuation located above tsunami wave height.

Indonesia is a country that prone to tsunami, as an example for islands that are facing the Indian Ocean (such as Western part of Sumatra Island, Southern part of Java, North side of Papua, Nusa Tenggara, Sulawesi and Maluku, and East part of Kalimantan Island). Indian ocean is the meeting location of the Eurasian plate, the Indo-Australian plate and Pacific plate. Approximately 90% of the Indonesian tsunami events are caused by a bottom uplift fault mechanism, and 10% are generated by volcanic eruptions and landslides (Behrens, 2008).

On December 26, 2004, the Sumatra tsunami was the known global tsunami that damaged coastal regions of the Indian Ocean in 12 countries, namely: Indonesia, Thailand, Myanmar, Malaysia, India, Sri Lanka, Bangladesh, Maldives, Somalia, Kenya, Tanzania, and South Africa. This event killed more than 230,000 people, injured almost 283,000 people, and cause deaths of nationals from 73 countries (Joseph, 2011).

Pacitan sub-district is an area with bay topographic, located in south part of East Java that is facing the subduction zone (between Eurasian Plate and Australian Plate) and prone to tsunami hazard. This area is the capital of Pacitan district that is dominated by flat terrain, and surrounded by hilly areas. The main tourist attraction in this area is Teleng Ria beach with number of visitor who visit this area were 317,453 people in 2014 which equal to 28.6% of the total visitors who visit Pacitan District (Statistic, 2015).

In case of potential hazard in Pacitan area, the distribution of population is the important thing that need to be considerated. In the coastal area, number of tourist in tourism location, number of population in day and night time need to be considerated in the process of evacuation planning. Those population dynamic is very important for government to provide the shelter location that can allocated the number of people that can affected by tsunami. A tsunami evacuation plan is a part of local disaster management and the primary responsibility of local authorities to save lives (GTZ-IS & GITEWS, 2010).

This study aims to determine the suitable location for tsunami evacuation building sites and evacuation routes based on population dynamic and human behavior in disaster evacuation in Pacitan coastal area. Different scenarios in this research including a day time scenario considering the presence of tourist, a day time without considering tourists, a night time with considering the presence of tourist and night time without considering tourists.

1.2 RESEARCH PROBLEMS

The number of potential population exposed to a tsunami can be reduced if each country provides a good prevention and preparation plan. Japan has developed tsunami prevention and preparedness plans using tsunami breakwater constructions and evacuation plans (Shibayama et al., 2013 ; Suppasri et al., 2013). An evacuation plan is important to minimize the number of victims for example by optimizing the existing road and building resources as elements for evacuation. An evacuation plan should include clear information about the hazard zonation, safety zone, evacuation sites, and evacuation routes.

In case of evacuation, Santos, Tavares, & Queirós (2015) described that to evacuate residents and tourists using a car will create heavy traffic, car accidents and fatalities. Sutikno, Murakami, & Suharyanto (2010) also explained that residents tend to use their vehicle for evacuation, because a car or a motorcycle is one of the expensive belongings. The evacuation with vehicle sometimes causes a traffic jam and traffic accident, and obstructs the connectivity of evacuation networks. Therefore, evacuation by walking seems to be the most effective way. Further, average human speed can be considered to determine the optimal evacuation route based on estimation tsunami arrival time. In determining the most suitable evacuation location, human behavior aspects are also need to be analysed. Huang & Wu (2011) in her research applied expected human behavior during evacuation in general disasters, such as choosing the most familiar path, avoiding danger, move towards a bright place, follow the crowd, choose straight route, move towards more larger space, and choose the closest route or stairs to evacuate. Moreover, it is necessary to determine building shelter capacity and location to define people accessibility and ability to go to that location in the limited time before tsunami occur.

Pacitan developed evacuation plan by using horizontal shelter location in elevated area. People was educated and socialized to evacuate by running to the higher place (shelter location). Pacitan as tourism area create a possibility for foreigner to visit this area. In that case, the population dynamic in this area that also including foreigner need to be considered in developing evacuation plan. Predicted evacuation time that limited in Pacitan ensure the needed to have additional shelter location in Pacitan lowland area. Therefore in defining new shelter location, human behaviour in disaster evacuation and shelter capacity estimation need to be considered. Based on the problems mentioned above the research problems of this study is : how to manage the population dynamic in case of determining shelter location and route for tsunami evacuation plan by considering human behavior during evacuation.

1.3 RESEARCH OBJECTIVES

The main objective of this research is to determine the most suitable tsunami evacuation building locations and the optimal evacuation routes based on population dynamic in day and night time and considering tourism and human behavior in disaster evacuation in Pacitan sub-district area.

To achieve the main objectives, the following specific objectives have to be obtained :

1. Finding the most suitable tsunami vertical evacuation building criteria based on literature study
2. Analyzing tourist perspective related to human behaviour in disaster evacuation to determine the potential tsunami evacuation building location.
3. Analyzing the existing tsunami horizontal evacuation locations.
4. Analyzing the population dynamic in day and night time, with considering with and without tourist scenarios based on population data and field work.
5. Analyzing tsunami shelter accessibility and ability for population based on land use and slope condition and shelter capacity.
6. Determining an optimal tsunami evacuation routes in each shelter location.

1.4 RESEARCH QUESTIONS

Research questions on table 1.1. were addressed to achieve the objectives.

Table 1.1. Research Objectives and Research Questions

Research Objectives	Research Questions
Research Objectives 1	a) What are the criteria for vertical evacuation buildings based on literature study? b) What are the most suitable criteria for vertical evacuation buildings to be applied in Pacitan study area?
Research Objectives 2	a) What is tourist perspective related to human behaviour in disaster evacuation based on interview result b) What is the existing multi function building type and location that is suitable for tsunami vertical evacuation? c) How is the capacity of existing vertical building to accommodate people?
Research Objectives 3	a) Where is the location of existing tsunami horizontal evacuation? b) How is the condition and capacity of the location to accommodate people?
Research Objectives 4	a) How is the population distribution based on the building use condition in day and night scenario without tourist? b) How is the population distribution based on building use condition in day and night scenarios with tourist?
Research Objectives 5	a) How can slope aspect affect the human speed of evacuation? b) How is population ability to evacuate based on estimation tsunami arrival time and existing evacuation building capacity in day, night, with and without tourist scenarios? c) In case of inadequate building shelter, how many additional vertical building are needed based on population numbers in the different scenarios?
Research Objectives 6	What is the most suitable evacuation route modelling to be applied in Pacitan study area?

1.5 RESEARCH BENEFIT

The result may give benefits such as :

1. Tsunami evacuation plan scenario can be used to improve the existing evacuation plan by considering population dynamic in the day and night

scenario, and also with and without tourist scenario and human behavior in disaster evacuation.

2. The assessment of multi-function buildings that can be used as shelter.

1.6 RESEARCH STRUCTURE

This research consist of 6 chapter, including :

- **Chapter 1** addresses the issue about the introduction of the research, including background, research problems, research objectives, research questions, research benefits, and research structure.
- **Chapter 2** is about research literature study that describing tsunami, evacuation plan, vertical evacuation building criteria, evacuation speed, tessellation, and evacuation modelling.
- **Chapter 3** describes study area in terms of the geography, land use, the population aspect, and potential tsunami hazard in Pacitan.
- **Chapter 4** explain research methodology used including research design, pre field work, field work and data processing.
- **Chapter 5** discuss about input data including slope, land use, shelter location and human speed test.
- **Chapter 6** is about population modelling that include population data, population estimation, population without tourist scenario and population with tourist scenario.
- **Chapter 7** describes evacuation modelling that include accessibility and ability modelling.
- **Cahpter 8** discuss about evacuation route modelling including the comparison of route modelling method and finding the closest facility.
- **Chapter 9** discuss discussion, conclusion and recommendation of this research.

CHAPTER 2.STUDY LITERATURE

2.1 TSUNAMI

The tem *tsunam*i is Japanese, means harbor (*tsu*) and wave (*nami*), because it was first observed by Japanese fisherman when found their harbor and houses destroyed by sea waves that often develop as resonant phenomena in harbors after offshore earthquakes (Bryant, 2014 ; Olson & Wu 2010). Olson & Wu (2010) define tsunami as water waves that come up due to mechanical disturbances in water bodies such as oceans, ocean bays, or lakes but also in artificial reservoirs (dams).

Fema P646A (2009) categorized tsunami into three, far-source, mid-source and near-source. A far-source-generated tsunami originates from a far source from the site of interest, and takes 2 hours or longer after the triggering event to arrive. The originating earthquake or landslide will likely not be felt before the first wave arrives, the warning will come from the tsunami warning center. In the December 2004 Indian Ocean Tsunami, Sri Lanka suffered major damage despite being located 1,000 miles from the earthquake that triggered the tsunami. A mid-source-generated tsunami is one in which the source is somewhat close to the site of interest, and would be expected to arrive between 30 minutes and 2 hours after the triggering event. A near-source-generated tsunami is one that originates from a source that is close to the site of interest, and arrives within 30 minutes. The site of interest might also experience the effect of the triggering event. For example, the 1993 tsunami that hit Okushiri, Hokkaido, Japan, reached the shoreline within 5 minuter after the earthquake.

Tsunamis not only occur on the open sea, but also in other water bodies such as bays, inland seas, and lakes. The greatest tsunami run-up occured in Lituya Bay, Alaska on July 9, 1958. Inland sea are also prone to tsunami like the one that happenned in Bulgaria, with maximum probabilities of tsunami run-up until 10 m heights. Tsunamis are also possible to occur on the small lake, like the one that happpenned in Burdur Lake in Turkey (Bryant, 2014b). Tsunami occur as a result of various sources such as sea floor earthquake (sea-quake), landslides (surface/submarine), volcanic eruptions, meteorological disturbance, and asteroid impacts. Based on figure 2.1., 82% tsunami events were caused by seaquakes, although not all seaquakes is tsunamigenic. Seaquakes main parameters are the epicenter location, depths (shallow / intermediate) and magnitudes. Minimum magnitude required for a large tsunami generation is about 6 Richter scale (Joseph, 2011). As an example, the Indian Ocean tsunami on December 26, 2004 that occured with magnitude was estimated betwen 9.15 and 9.39 followed by a tsunami that spread onto coastal plains in Sumatra, Thailand, India and Sri Lanka (Bryant, 2014).

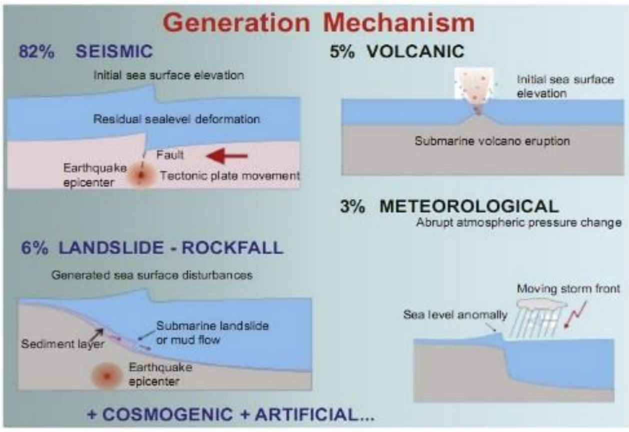


Figure 2.1. Illustration of tsunami generation mechanisms (Source : Joseph, 2011)

Submarine landslides generate tsunamis only when the material moved at a great speed and also have been found to be dominated associated with low tide. Skagway Harbor tsunami waves in Alaska occured about 30 minutes after low tide. In some cases, landslides are triggered by earthquake. The Grand Banks landslide-generated tsunami of November 18, 1929, was trigered by 7.2 richter scale earthquake that occurred at the southern edge of the Grand Banks, located 280 km south of Newfoundland, at an estimated depth of 20 km beneath the seafloor (Fine et al., 2005; Clague, 2001 in Joseph, 2011).

Around 5% of tsunami are generated by volcanic eruption like at Krakatau Island in Indonesia on August 27, 1883. The Krakatau Island volcano exploded and created a series of large tsunami waves with reaching height over 35 meters above sea level, and took a toll of 36,000 lives in western Java and southern Sumatra (Murty, 1977; Bryant, 2001 in Joseph, 2011).

Long waves generated by atmospheric forcing (part of cyclones and hurricanes, frontal squalls with associated thunderstorms, atmospheric gravity waves, atmospheric pressure jumps, wind waves) can also be responsible for significant, even devastating long waves or “meteorological tsunamis” (meteo-tsunamis) because they have the same temporal and spatial scales as typical tsunami waves. As an example, the one that is occured on June 21, 1978 in Vela Luka, which is a small town hidden in a bay on Korcula Island in the Adriatic Sea. Meteo-tsunamis are similar in appearance to tsunami waves that can affect the coasts in the same damage, although the catastrophic effects normally observed only in specific bay and inlets. (Vucetic et al., 2009 in Joseph, 2011).

Asteroid impact is beyond human response, for instance the one at Chicxulub, Mexic generated 180-200 km diameter crater, and then triggered mass flows and tsunamis in the Gulf of Mexico and adjacent areas over 65.5 million years ago (Joseph, 2011).

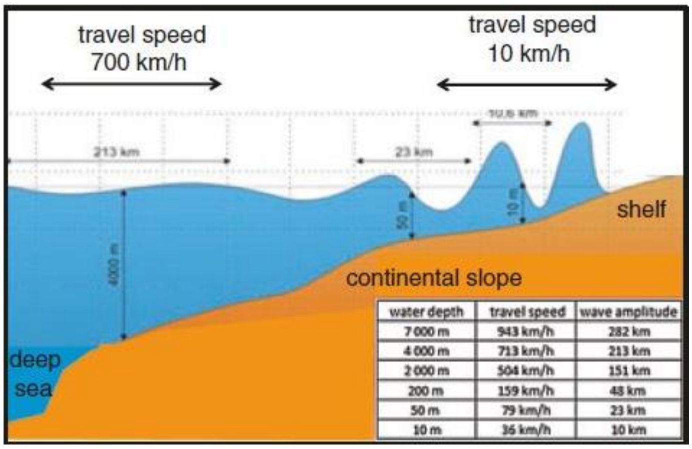


Figure 2.2. Tsunami Travel Speed, Wave Height and Amplitude (Courtesy Franzius Institute, University of Hannover) (Source : Olson & Wu, 2010)

Tsunami sources cause a disturbance of the entire water body from the sea floor up to sea level. In tsunami event, entire water column is agitated, a water column of 4-5 km can be in motion in the open ocean. From the source generation, the tsunami can propagates in all direction. In the open ocean tsunami speed can reach up to 900 km/h with only marginal rise in the sea level but wave amplitudo more than 200 km. While entering the shelf, tsunami speed and wave amplitudo decrease to about 60 until 80 km/h and on the shelf about 10-30 km/h as can be seen on figure 2.2. This reduction causes increasing on the wave height up to 30 m or more at landfall (Olson & Wu, 2010).

Misconception about tsunami is that a single, very large wave breaks onto the shore. A tsunami is not a single breaker, but usually encompasses a series of waves separated by minutes to an hour or more (Clague et al, 2003 on Mardiatno,D., et al , 2007). Generally the second and the third wave is the largest as it was observed in December 2004 in Banda Aceh (Lavigne et al, 2006 on Mardiatno, D., et al, 2007). In tsunami, wave run up is the important factor to predict the impact to the coastal area (Mardiatno, D., et al, 2007).

Tsunami run-up height depends on the shore configuration, diffraction, standing wave resonance, the generation of edge waves that run at right angles to the shoreline, the trapping of incident wave energy by refraction of reflected waves from the coast, and the formation of Mach–Stem waves (Wiegel 1964, 1970; Camfield 1994 in Bryant, 2014). The coastal morphology defines the impact of where and in which the direction of tsunami makes landfall. Steep cliffs create "a pilling up" of the water, whereas gently inclined coastlines give ample space for wide inland intrusion. The impact of tsunami is described by the water height /run-up heightand distance the water penetrated the land (inundation distance) as can be seen on figure 2.3. (Olson & Wu, 2010).

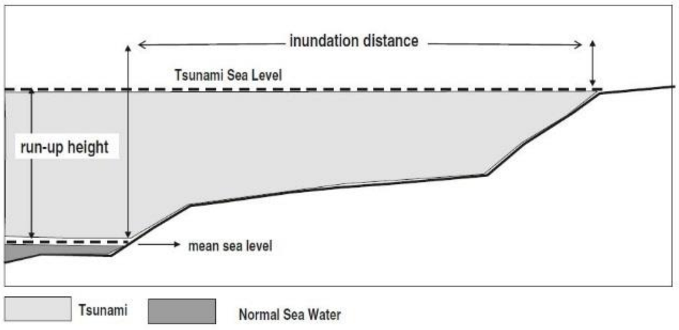


Figure 2.3. Tsunami run-up and inundation (Source: Olson & Wu, 2010)

Run-up heights is normally twice the ammount of the fault slip amount, such as the 2004 tsunami fault of 10 m that create run-up height more than 20 m. Inland penetration of a tsunami can be roughly estimated. On a very smooth flat-lying terrain with low topographic roughness, inland penetration can be up to several km (example at a run-up height of 10 m). In contrast, a steep cliff will only be inundated by several tens of meters and the run-up height can reach more than 20 m. A coastal area that is densely populated with buildings close to the shoreline or coastal rim covered with trees and bushes both hamper the flood form penetrating far inland. The more densely a tsunami-exposed terrain is covered by buildings and/or trees, the less the waves are allowed to penetrate inland (Olson & Wu, 2010).

2.2. EVACUATION PLAN

Tsunami evacuation plans should be acknowledged as an official government document. This makes it credible and binding reference for institutions for all levels of governments, NGOs, private sector, and local population, so they can use these plans to develop their own evacuation procedures (Spahn, Hoppe, Usdianto, & Vidiarina, 2010). Tsunami evacuation plan should guide all affected people along the evacuation routes towards safe place (outside the reach of tsunami waves) also assembly facilities or emergency shelters, in time (time span between alarm and arrival of first wave taking into account for each person the distance to the next emergency shelter). Moreover, evacuation plan should foresee that a single assembly facility that can cope with the expected number of people that are supposed to use this facility. Tsunami evacuation plan is generated on the two groups of parameters. First, number of people affected per location, location, roads and distances, the accessibility and the safety of these, after a preceding earthquake. Second, maximal expected wave weight and assumption on time lap until first wave arrival (S. Scheer et al., 2011; S. J. Scheer et al., 2012).

Evacuation plan is kind of strategy for saving lifes before tsunami waves arrive by evacuate people from hazard zone. There are 2 methods in evacuation plan for tsunami (National Tsunami Hazard Mitigation Program, 2001) :

a. Horizontal evacuation, by moving people to more distant/higher location.
b. Vertical evacuation, by moving people to higher floors in building.

FEMA P-646 (2008) proposed a combination of vertical evacuation facilities and the use of natural high ground for evacuation when available. This concept was illustrated on the figure 2.4. Two or more shelters may be needed to provide the optimal solution. In that case, a proper shelter location should be selected to obtain the shortest distance among multiple shelters for the evacuees. Shelters do not always need need to be new construction; rather, they can be selected from existing structure in the community such as a city hall, hospital, school or fire station (Park, Lindt, W., Gupta, & Cox, 2012).

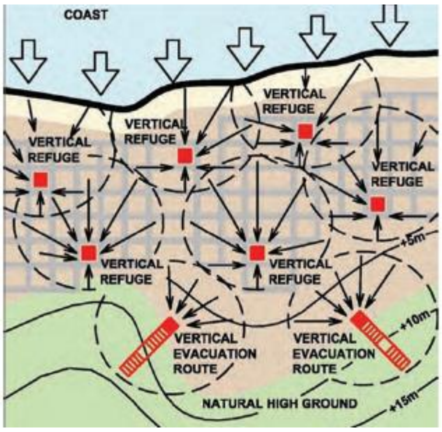


Figure 2.4. Shelters as an evacuation plan from FEMA P-646 (Source : Fema P646A, 2009 ; Park et al., 2012)

a. Horizontal Evacuation

Horizontal shelters are designated on safe areas in a sufficient amount of evacuees for the time of inundation. These sites should be easily accessible, located at rational distance from the point of departure, have the capacity for allowing appropriate number of persons to fit in and should have access to drinkable water, phone, electricity emergency kits, etc (S. Scheer et al., 2011).

b. Vertical Evacuation

If evacuating to natural high ground is not possible or practical, vertical evacuation is a potential solution. A vertical evacuation structure is a more expensive option than going to natural high ground and should be targeted to individuals who cannot remain at their location at the time of the event yet cannot evacuate to high ground (Fema P646A, 2009).

2.3 EVACUATION TIME

Tsunami arrival time can be defined as time from the tsunami generation until the first wave reach at the coastal area, and calculated based on numerical modelling result that considering the tsunami arrival time and response time. The response time can be obtained from the existing emergency protocols or from the responsible authorities, at least the information regarding the detection and warning, alert transmission and reception times, and population reaction. If there are no information retaled to population reaction time, may be assumed to be 15 minutes for prepare/aware (P. González-Riancho et.al., 2013). Joachim Post (2011) explained that the ability to respond properly to a tsunami warning message, depends on (1) location of tsunami safe areas, (2) land cover, (3) topography (slope), (4) population density, (5) age and gender distribution and (6) critical facilities density (primary schools, hospitals). The location of safe areas determines the distance an evacuee has to cover. Land cover and slope alters the evacuee's movement and speed (ADPC, 2007). Related to demographic factors it has been found in several studies that age and gender distributions significantly impact fatality rates due to contributions to longer evacuation times (Johnson, 2006). In evacuation modeling, the impact of population density and evacuation properties of different group sizes are accounted. The larger the group and the higher the population density the slower the evacuation process (Klüpfel, 2003). Critical facilities like schools and hospitals result in reduced response capabilities due to the presence of people needing special attention during an evacuation (Johnson, 2006).

Figure 2.5. illustrate the reaction scheme and time sequences of an early warning system from the moment of tsunami warning detection until the evacuation of the population at risk.

a. **Warning** decision is the task from responsible authorities to monitor and detect impending disasters, aggregate and condense these information to provide reliable information to decision maker, whether to warn or not, disseminates the warning message and inform this to people at risk. This warning decision process is estimated takes time about 5 minutes.
b. **Warning dissemination,** including local stakeholder strategy to spread the warning information to the majority of the population. This requires setting up extensive local warning infrastructure by taking into consideration local and cultural capacities for warning receipt and communication of the population.

Mobile phones are one of the communication media considered suitable for use in Indonesia. Dissemination process from local stakeholder to community is estimated to takes time until 10 minutes (GTZ 2007).

c. **Warning receipt by the population,** is the analysis about how many people that still do not receive warning information when local government specify type of strategy like using mobil phone. If the amount of people that do not receive information is more than people that receive the information, local stakeholder need to improve another strategy like using sirens or mosques that can access to outdoor. Warning receipt by the population is estimated takes time until 30 minutes (Post, 2011).

d. **Warning reaction,** including people reaction after earning dissemination. This part is related with people action in defining evacuation place and routes, family based rule son meeting points, plans for the usage of vehicle and support for the elderly. This part is estimated takes time until 30 minutes

e. **Evacuation,** needs to be developed by local stakeholders whose tasks are to ensure that their citizens manage save evacuation in due time. Disaster Risk Management tasks include defining the evacuation zone, developing evacuation infrastructure for horizontal and vertical evacuation and evacuation routes to shelters.

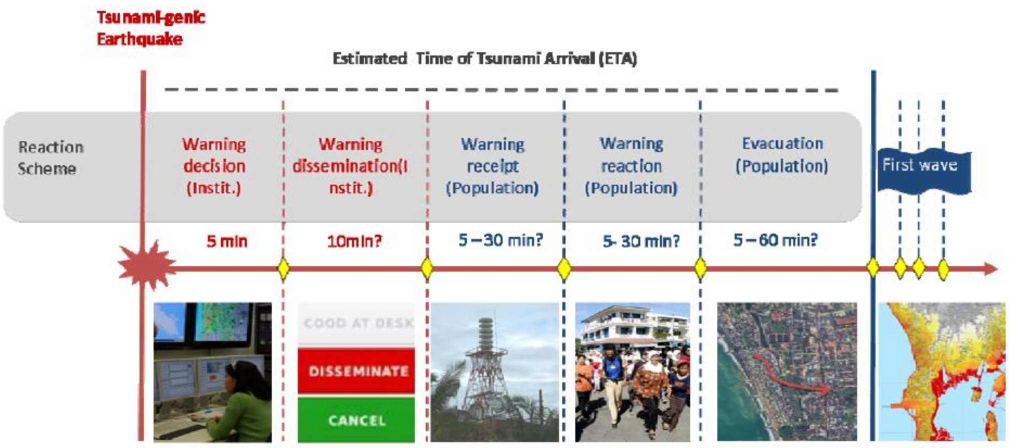


Figure 2.5. Reaction Sheme of People in Early Warning Systems
(Source : Joachim Post, 2011)

The tsunami travel time in Indonesia is generally short (local tsunami), ranging between 20 until 45 minutes after the earthquakes. Arrival time for tsunami in South Java is assumed around 20 minutes, thus the maximum time for evacuation to the safer places is proposed 15 minutes maximum (Mardiatno, 2008a).

2.4. VERTICAL EVACUATION BUILDING CRITERIA

S. J. Scheer et al., (2012) described that vertical shelters are an earthquake-proof buildings (i.e., reinforced, concrete with more than two storeys) existing within the tsunami hazard zone. In addition, buildings selected as vertical shelters must also be able to withstand the hydraulic forces of the incoming waves, and withstand also severe damages created by floating debris and huge objects carried forward with the incoming waves or brought back during the backwash. These selected buildings must have a height sufficiently above the maximum water height. An empirical formula for estimating the height above which vertical evacuation is considered safe is (Ranguelov,2011;Yehet al.,2005):

Safe height = (Max Wave height * 1.30) + 1m

Exploring existing structures as potential vertical evacuation facilities should become priority if there is no naturally high ground inside the inundation zone. Multistory buildings, such as larger concrete frame structures like hotels that meet seismic standards could be appropriate choices for vertical evacuation structures with some strengthening. There are some types of vertical evacuation including : existing or engineered high ground, parking garages, community facilities (community centers, recreational facilities, sport complex, libraries, museums, police station and or fire stations), commercial buildings (hotel, condominiums, restaurant), and school facilities (Fema P646A, 2009).

In Indonesia, The National Disaster Management (BNPB, 2012) proposed that tsunami evacuation shelter should an earthquake resistant building, building floor is more than tsunami height prediction, and public facility building in normal condition (without tsunami). Public facility like mosque, school, hospital, office, and hotel can also be used as evacuation location. Tsunami shelter building include thre main part, the bottom, the up, and the roof of the building . Bottom part of building can be used as daily parking vehicles. Parking lots are open, allowing water to flow unimpeded tsunami. The top floor of the building is in the form of function rooms which can be used for various activities. The roof of the building can also be used as an evacuation that can accomodate 100 people, also possible for a helicopter to provide assistance. Shelter should be located in the crowded and strategic place. In defining tsunami building shelter criteria, there are some researcher that define the criteria in Indonesia:

1. Tsunami Building Shelter Criteria in Aceh

Budiarjo (2006) on his research propose some criteria to define tsunami shelter building based on tsunami-survived building survey in Aceh. The observed building components include architectural component (wall, openings, doors, roof, floor) and structural (column, beam, foundation, lateral bracing, roof frame). If the remaining functioned building components are less than half of the whole building, the building is not considered as resistant or tsunami-survive building. More than 75 % building components that are destroyed and can still be functioned, are shown on figure 2.6. Generally the survived building criteria in Aceh, describe in following :

Figure 2.6. Moderate-resistance surveyed building
Sources : Budiarjo (2006)

- At least building located at distance of 200 m from the shore.
- Building mass that situated in the same direction with the waves is found to be more resistant than the one blocked by the wave flows.
- Large percentage of openings such as door, window, and air ventilation exist in the facade tsunami-survived buildings prevented the destruction of the buildings. Facade comprises corridor, opening arch, and terrace or porch had proven to support the building resistance since they can allow the wave flows.
- Structural design of the surveyed buildings are reinforced concrete structure, with fulfil basic requirement of horizontal and vertical load distribution based

on dimension of column, beam, slab, lateral bracing.

An evacuation building in Banda Aceh as on figure 2.7. have been designed with four stories and an overall height of 18 m, and incorporates 54 columns each having a diameter of 70 cm. The roof includes helipad for helicopter landing. The second floor has a height of approximately 10 m, as indicated by the 26 December 2004 tsunami wave height at the location of the building. The first floor is left open with no partitions or hollow structures, following the concept of the mosque. The aim is to avoid the wave force of future tsunamis. The building can accommodate the evacuation of 500 people and is designed to withstand earthquakes with a moment magnitude of 10 on the Richter scale. The stairs leading to the upper floor is made of two parts. One main staircase has a width of 2 m and another one has a width of 1 m with the slope designed to accommodate the use of wheel chairs in emergency situations. The building is also equipped with facilities for emergency situations. The building serves as a community center that is surrounded by villagers who are alert and ready to mitigate the effects of disasters (Suppasri et al., 2015).

Figure 2.7.
(a) Evacuation Building in Aceh
(b) Building Design
(Source : Suppasri et al., 2015)

2. Tsunami Building Shelter Critria in Padang

Ashar, Amaratunga, & Haigh (2014) determined temporary evacuation shelter in Padang city with some criteria, including : schools that have a strong structure, building with three storeys, and building with roof which served as a tsunami evacuation and mosque with capacity of 1500 people.

In addition, S.Sutikno (2015) explained that Padang city government with the aid of the international donors has built buildings shelter, such as schools with strong structure, three storeys, and roof which served as a tsunami evacuation.

3. Tsunami Building Shelter Criteria in Pacitan

Papathoma Tsunami Vulnerability Assessment (PTVA) model was applied by Mardiatno (2008a) in Pacitan building vulnerability assessment by scoring system. Building vulnerability assessment include some parameter such as building construction, number of floors and building height. Building construction classified into three categories, weak, medium and strong. Weak building strength category is for partly permanent and moderate building types with wall using bricks partly, fieldstone, wood, bamboo, unreinforced, crumbling and/or deserted. Medium building strength category is for partly permanent, good permanent, and moderate building types with building bricks partly and/or whole, cement mortar, and no reinforcement. Strong building strength category is for permanent and good bulding types with building bricks, pre-cast concrete skeleton, and reinforced concrete. Number of floors classified into three categories, high, medium, and low. High vulnerable building is for 1 floor building with height less than 8 m. Medium vulnerable building is for 2 floors building with height more than 8 m and less than 12 m. Low vulnerable building is for more than 2 floors building with height more than 12 m. At the end of scoring system, building value were classified as shown on table 2.1.

Table 2.1. Building Value

Category	Index	Building Types and Quality	Explanations
High	1	Permanent; good	Building bricks, pre-cast concrete skeleton, reinforced concrete. 1 storey or more
Medium	0	Partly permanent;good Permanent;moderate	Building bricks partly and/or whole, cement mortar, no reinforcement, 1 storey
Low	-1	Partly permanent; moderate	Wall using bricks partly, fieldstone, wood, bamboo, un-reinforced, crumbling and/or deserted, 1 storey

Source : Mardiatno (2008a)

From different perspective, Sutikno, Murakami, & Suharyanto (2010) propose mosques as temporary shelter because of the local wisdom in Pacitan. Mostly, Pacitan people are Islamic religious, and each village have at least one mosque for praying together in their community five times everyday. The mosque is recognized as a quasi-public place for residential people, and it usually has a structure with plural floors. Some types of mosques have proven in 2004 Aceh tsunami event that they were still standing while the other building collapsed because of their unique architecture.

Due to the limitation tsunami hazard result that only considering flow depth, in this research, building criteria to define propose shelter building was referred from Budiarjo (2006) and Mardiatno (2008a). The criteria are :

a. At least building with medium building strength category for partly permanent, good permanent, and moderate building types with building bricks partly and/or whole, cement mortar, and no reinforcement.
b. At least building with 2 floors.
c. Minimum building location, that should 200 m from the shore.
d. Building mass that situated in the same direction with the wave flows.

2.5. EVACUEES SPEED

2.5.1 Human Speed Based on Age Classification

Lee et al, 2004 emphasized walking speed as a very important factor in evacuation analysis for human safety. C.H. Huang & Wu, (2011) considering human walking speeds based on Lee et al, 2004 on the table 2.2.

Table 2.2. Average walking speeds of human

Item	Walking Speed (m/s)	Item	Walking Speed (m/s)
Rush	2.5	6-10 (children)	1.12
15-40 (men)	1.52	Elder	0.92
<50 (women)	1.38	Woman with a child < 6	0.72

(Source : Lee et al., 2004 in C.-H. Huang & Wu, 2011)

Fraser et al. (2014) also mentioned various age group condition walking speed based on previous researcher as shown in Appendix 1.

2.5.2 Human Speed Based on Slope Condition

In case of topographic area, variation of slope will affect the human speed of walking. P. González-Riancho et.al (2013) describe the evacuation speed correction based on slope on the following table 2.3.

Table 2.3. Evacuation speed correction based on the slope

Slope (%)	**0-3**	**3-6**	**6-9**	**9-12**	**12-15**	**15-18**	**18-21**	**21-24**
Value (%)	100	85	70	55	45	40	35	30
Slope (%)	**24-27**	**27-30**	**30-33**	**33-36**	**36-39**	**39-42**	**42-45**	**> 45**
Value (%)	25	20	15	14	13	12	11	10

(Source : Laghi et al, 2006 in P. González-Riancho et.al, 2013)

2.6. TESSELLATION

In this research, tessellation was used to concentrate population. Tessellation is defined as sets of connected discrete two-dimensial units (Laurini and Thompson, 1992 on Dewi, 2010). A tessellation provide a way to deal with space occupancy. There are two kind of tessellation, irregular and regular. Irregular are used in areas like zonal for social, economic, demographic and administrative data. Regular are benefit in image data remote sensing. (Laurini and Thompson, 1992 on Dewi, 2010). An irregular tessellation is configuration of polygons of polyhedral of varied shape and size. The basic spatial units of a tessellation can vary in size, shape, orientation and spacing (Dewi, 2010). Hexagon tessellation was used in this research because the shape has a shorter perimeter than a square of equal area, which potentially reduce bias due to edge effect (Krebs, 1989 on Dewi, 2010). Hexagonal teselletion created using ArcGIS extension from Whiteaker (2015) reffer to study area coverage. Each hexagonal tessellation then will be presented as point form that consist of information related to number of population in each tessellation in different scenario.

2.7. MODELLING

2.7.1 Tsunami Hazard Modelling

Tsunami hazard modelling aim to simulate tsunami generation, propagation and subsequent inundation. The tsunami simulations depend on : a) the initial fault mechanism; b) the hydraulic conditions (DEM, cell size); also the earthquake information that available immediately after the event related to epicentre, magnitude and depth (Franchello & Annunziato, 2012). There are some examples of tsunami inundation simulation using numerical models.

Community Modelling Interface for Tsunamis, ComMIT (Titov et.al., 2011); Australian National University and Geosciences Australia model, ANUGA (Nielsen et.al, 2005); Cornell Multi-grid Coupled Tsunami model, COMCOT (Wang and Liu, 2007); and Tohoku University's Numerical Analysis Model for Investigation of tsunami, TUNAMI (IUGG/IOC TIME Project, 1997) (Srivihok et al., 2014).

TUNAMI is an example that have been applied by Mardiatno (2008a) in Pacitan. Mardiatno (2008a) using 4 grid sizes, i.e. 810 m, 270 m, 90 m and 30 m in defining grid row and column as parameter in TUNAMI program. Bathymetric map with scale 1:10.000 and direct field measurement used as input data. Three inundation models to determine tsunami hazard potential, including (1) inundation model based on elevation (or called simple model); (2) inundation model based on terrain roughness coefficients, and (3) inundation model based on 2D tsunami wave inundation model (TUNAMI) variables have been included in the calculation. A simple model can be applied for tsunami hazard potential mainly when data on farthest tsunami inundation is not available. In this model, the attention is provided only to inundation possibility under definite elevations. A roughness coefficient-based model generates various scenarios (maximum and minimum) of inundation distance using variety of wave heights (in this research Ho=5m, Ho=9m and Ho=12m). Tsunami wave model using TUNAMI provides a complete analysis of hazard potential, i.e. from the initial condition (wave source), tsunami propagation and inundation, based on a hypothetic epicentre (110.0ºE ; -9.5ºS) and earthquake magnitudes (Mw= 7.5 ; 8.0 and 8.5).

Another researcher, Muhari, Diposaptono, & Spahn, (2012) using SRTM 30 m data for numerical modelling using earthquake scenario with Mw=8.5. He assumed the strike, dip and rake as 284º, 12º, and 99º with additional slip in shallow sediment of 60º (the same value of additional slip as for the 1994 tsunami in East Java proposed by Latief). The result of this modelling show the information related to tsunami flow depth inland, with category class including of 0-2 m, 2-4 m, 4-6 m, 6-8 m, 8-10 m and 10 – 12m. Based on his result, tsunami is potentially flooding pacitan town with a maximum flow depth of 10.8 m and in average of 4 m. The area on the right hand side of the bay (right side of the river) is the lowest ground level in the numerical domain, with the deepest flow depth in the region.

2.7.2 Population Modelling

Population census data are the essential input to generate the population distribution during day and night for evacuation planning purposes. Population data from census survey are commonly made available per administrative level where the populations seem to be homogeneously distributed over the whole area, despite possibly significant variations in real population densities (Schneiderbauer, 2007 in Muck, 2008; Widyaningrum, 2009). Evacuation planning need detailed information on spatial and temporal population distribution, such that the idea to rescue all the people in the tsunami hazard area can be achieved (Budiarjo, 2006). Taubenböck et al (2008) describes that there are two methods for population disaggregation. Top-down approaches use statistical data and disaggregate population data spatially to derive the population's distribution. To increase the spatial resolution, ancillary data such as land use are used. There are two main methods in top - down approaches (Khomarudin, 2010).

a. Spatial interpolation, disaggregates tabular or statistic data to geospatially distributed information through various interpolation approaches.
b. Dasymetric mapping, is used to redistribute the number of people in an administrative unit to smaller units by using ancillary data such as land use.

Bottom-up approaches analyze the conditions of texture, impervious surface and other structures that can be derived from remote sensing data to estimate and extrapolate population distribution. Statistical data as well as sampling data from surveys are used for regression and correlation analyses to estimate the number of people in an administrative unit. Estimations of the number of people in an administrative unit on small scales like country or province yields good results with high accuracy; for large scales, this approach still needs some methodological improvements (Khomarudin, 2010).

In this research, the top-down approach was used to estimate population distribution based on dasymetric mapping. Dasymetric mapping in this research considering landcover data, focus on building use. Population number was estimated in 2 different category, based on settlement data (house) and non settlement data (public facility). Each tessellation will consist of different number of settlement and/or non settlement. Based on this condition, the population number can be estimated for day and night scenario.

2.7.3 Accessibility Modelling

Accessibility can be defined as the ability for interaction or contact with sites of economic and social opportunity (Farrow and Nelso, 2001). Mosley (1979) conceptualize the basic components of accessibility into: (1) the people, (2) the activities or services which people require, and (3) the transport that links between those two. The actual accessibility depends on each of the components of the following scheme (Muck, 2008).

In evacuation plan case related to the scheme above, people can be described as a given point where the affected population is consentrated. Activities can be described as an activitiy on the assembly point related to evacuation case. Transport can be defined as transportation (road and vehicle) that available from a given point to assembly point.

In this research, accessibility modelling in evacuation plan was visualized as coverage area by using CWD. Cost weighted distance (CWD) can be analyzed as a topographic surface, recognize mountains and valleys. This concept possible to define the area influenced by each evacuation point in watershed as can be seen on figure 2.8. The basins (catchment area) can be very useful, like identifying how many people stay inside each basin, and calculate the maximum evacuation time of each area and compare it with maximum acceptable time (Laghi, Polo, Cavalletti, & Gonella, 2007). In CWD concept, accessibility modelling produce information about evacuation basin (catchment area) with time values information based on slope, landuse, and average human speed as input data (ADPC, 2007;Muck, 2008).

Reclassification of the landuse and slope was the step to got a new value that describe capability to modify the speed of walking person. Average human speed and evacuation shelter point as input data have also to be set to create evacuation basin (catchment area) with time values information.

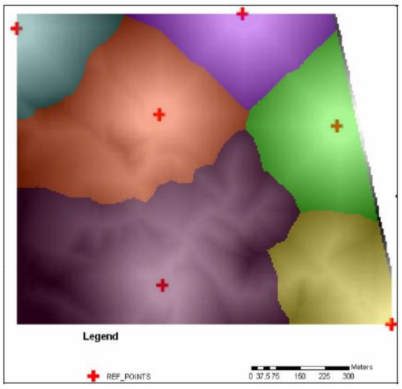


Figure 2.8. CWD surface computed using 6 evacuation points (Source : Laghi et al., 2007)

2.7.4 Ability Modelling

Ability modelling aims to know existing shelter ability to accommodate population in given time and the number of additional shelter that is needed. The evacuation shelter capacity and the time area (related to evacuees number) for each shelter building with a given evacuation time is important to be calculated. Based on figure 2.9., there are two possibility result in terms of number for people that in a given evacuation time. Firstly, is for L1 smaller than L2 and secondly, is for L2 smaller than L1. L1 (evacuation time area) defines the total number of people in a certain area who are able to reach the evacuation building in a given time which is derrived from the evacuation time map. L2 (evacuation shelter capacity area) defines the number of people who can be sheltered in the evacuation building in a given time considering building capacity from the tsunami evacuation building capacity (TEBC) calculation as follow (Widyaningrum, 2009) :

$$\textbf{TEBC} = \{(\textbf{Area}*\textbf{Capacity Score}*\textbf{Ammount of Building Floor})/1\textbf{m}^2\}$$

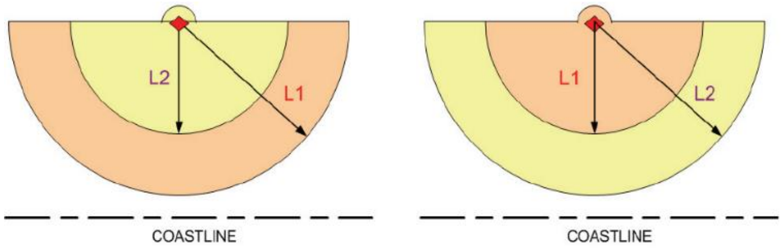


Figure 2.9. Evacuation Shelter Capacity and Time Area Approach

(Source : Widyaningrum, 2009)

2.7.5 Route Modelling

A network consists of a system of paths traveled by various things, such as traffic, water, sewage, or electricity. Common examples of networks include roads, utility lines, airline routes, and streams (Price, 2013). There are five types of network analysis layers, including : (ESRI, 2008 on Dewi, 2010).

a. Finding the best route, to find efficient travel routes from one location to another or the best way to visit several locations.
b. Finding the closest facility, to determine which facility or vehicle is closest, also give the best route to the facility.
c. Finding service area, to generate a region that covers all accessible streets that lie within a particular impedance.
d. Creating an OD cost matrix, to solve large problems quickly that doesnt contain information that can be used to generate true shapes or routes and driving directions.
e. Solving a vehicle routing problems, to give a high level of customer service by honoring any time window while keeping the overall operating and investment cost for each route as low as possible.

In this research, 2 of them are compared in this route modelling to finding the suitable routing method, including comparison for finding the best route, and finding the closest facility layers.

CHAPTER 3. STUDY AREA

3.1 GEOGRAPHY CONDITION

Pacitan regency is located between 7° 92' - 8° 29' South latitude, and between 110° 90' - 111° 43' East longitude. Pacitan regency administration boundary and the association with another region are mapped on the Appendix 2. Pacitan district/regency is divided into 12 sub-district and 166 villages, with government activity centralized in Pacitan sub-district (Statistic, 2016). Pacitan sub-district is bay topographic, dominated by flat area and surrounded by hilly area.

Pacitan directly facing Indian Ocean, the subduction zone between the India-Australian Plate and Eurasian Plate. Collision between these plates results in the endogenic activity in that zone being very dynamic. As a consequence, this area is very vulnerable to earthquakes. If earthquakes take place under seawater and there is a vertical dislocation in the seafloor, it will result in tsunamis (Mardiatno, 2008a). Pacitan sub-district consist of 25 villages,but the focus study area are only in Sidoharjo, Ploso and Kembang vilages as on figure 3.1.. These villages are categorized as coastal area because the location that directly facing ocean. Mardiatno (2008a) determined the piority areas to tsunami danger in Pacitan city based on 4 risk categories (risk of selected mobile asset, risk of building, risk of land function, and risk of population) in three inundation models to determine tsunami hazard potential. The total risk result as in Appendix 3. show that the 5 priority villages areas to tsunami danger in Pacitan sub-district are Sidoharjo, Ploso, Sirnoboyo, Kembang and Baleharjo. Based on the tsunami hazard modelling from Muhari, Diposaptono, & Spahn (2012) in Pacitan, 3 villages that are affected from tsunami in his modelling result are also including Sidoharjo, Ploso and Kembang. Moreover, Sidoharjo and Ploso villages are villages with the highest population in 2015 in Pacitan sub-district (Statistic, 2016). Based on limitation time on field and the reason explain before, the study area in this research focus on Sidoharjo, Ploso and Kembang villages.

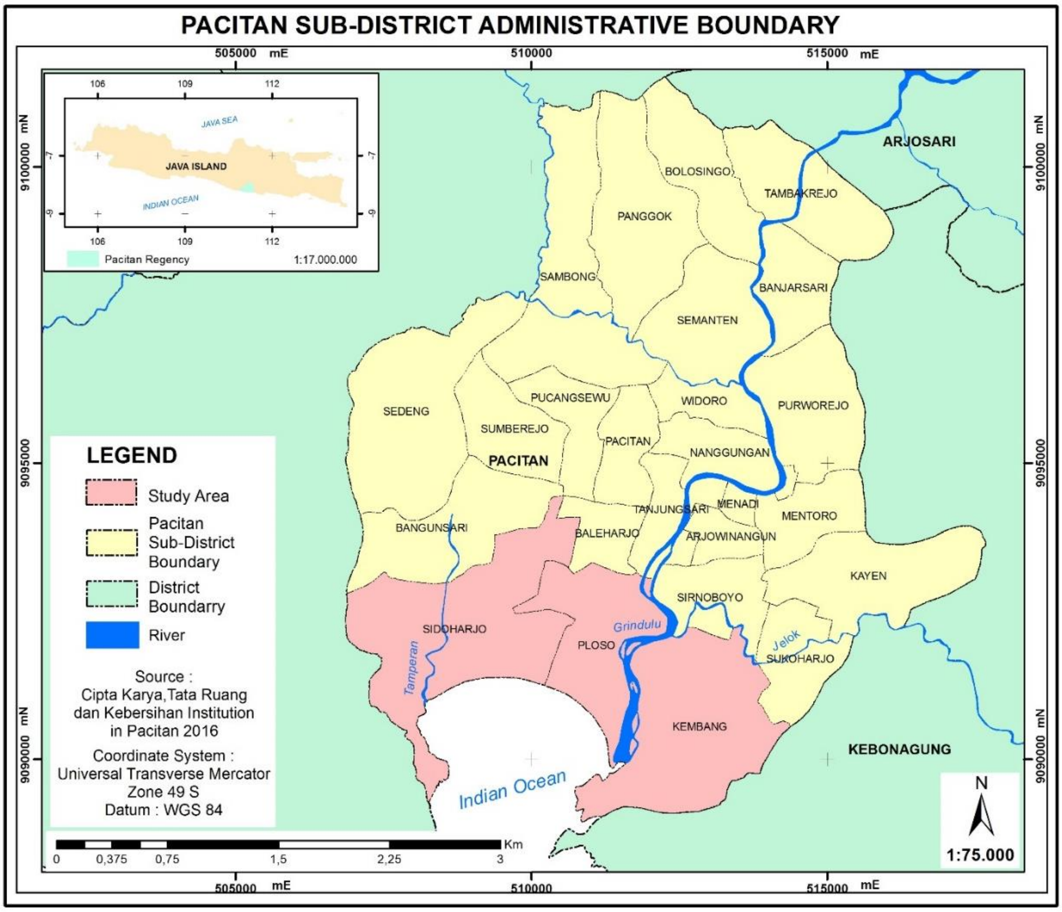


Figure 3.1. Pacitan Sub-District Administrative Boundary

3.2 LAND USE

Cipta Karya, Tata Ruang dan Kebersihan institution in Pacitan is institution that carry out tasks related to building system, housing system, sanitation and clean water. Land cover in Pacitan from this institution was generalized into land use class categories from ADPC (2007) as mapped on figure 3.2. Pacitan land cover by Cipta Karya, Tata Ruang dan Kebersihan institution were obtained from ikonos image 2012 interpretation and field survey method on 2016 only in Pacitan sub-district city boundary, not for the whole Pacitan sub-district area. As on figure 3.2., Pacitan city dominated by dense vegetation that include forest and forest production, and padi (rice field) landuse category.

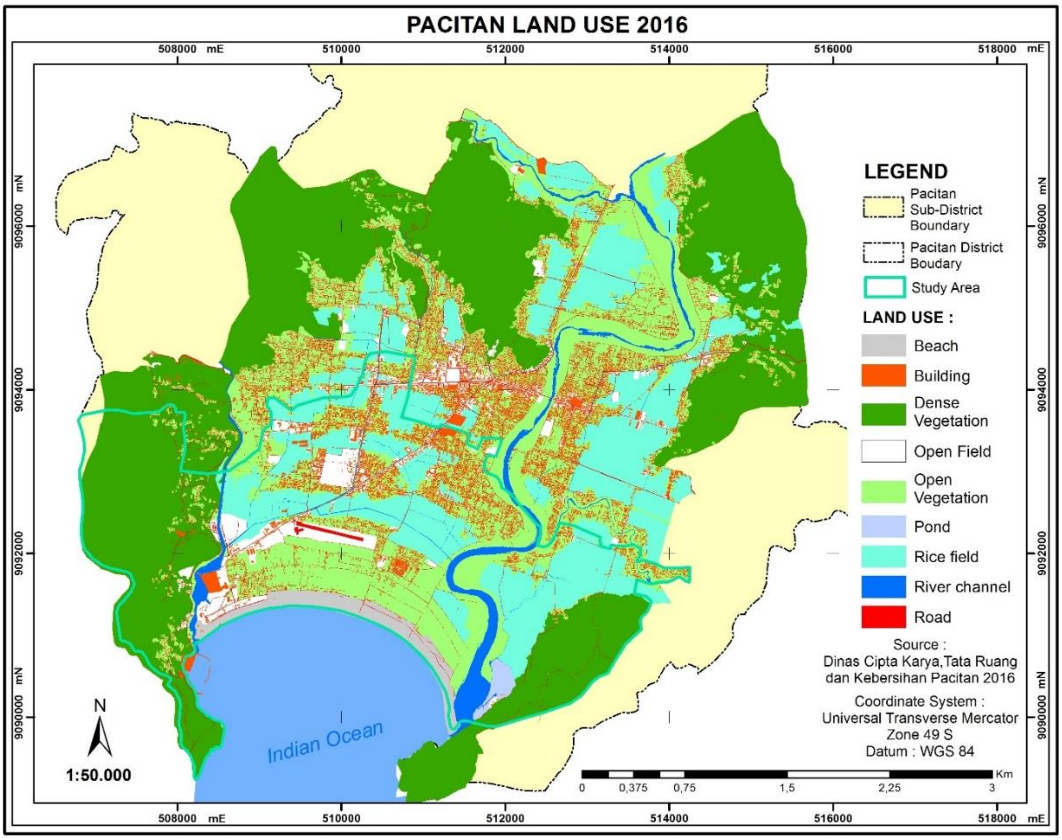


Figure 3.2. Pacitan Land Use 2016 (Source : Data Analysis, 2016)

3.3 POPULATION DATA

Pacitan regency population based on population projection for 2014 were 550,986 people consisting of 268,896 male and 282,090 female population. While the magnitude of the sex ratio in 2015 the male population towards the female population are 95.32. Pacitan sub-district as the seat of government have the highest population in Pacitan with 78,585 inhabitant following by Tulakan with 77,931 inhabitans. (Statistic, 2016).

Table 3.1. Population in Study Area, 2015

Villages	Population (people)	Households (hh)	Average people/hh
1.Sidoharjo	8,838	2,333	4
2.Ploso	6,798	2,133	3
3.Kembang	2,553	735	3

(Source : Statistic, 2016)

In specific, Pacitan sub-district population consisting 78,585 people of 38,257 male and 40,328 female population in 2015. The number of people in study area (Sidoharjo, Ploso and Kembang Villages) shown on table 3.1. (Statistic, 2016). It can be seen that in this research, Sidoharjo have the highest population in 2015.

3.4 TSUNAMI POTENTIAL HAZARD

Pacitan has never experienced a tsunami in the past (Latief et al, 2000 in Mardiatno, 2008a). Due to the limitation of tsunami hazard modelling result. In this research, **t**sunami hazard was referred to tsunami flow depth class based on modelling result. Flowdepth is more suitable than wave run-up to classify tsunami hazard potential, because run-up data only shows the vertical height above sea level of the tsunami at its furthest point inland (Paine 1999, Synolakis et al. 2005, Lavigne et al. 2007 on Mardiatno (2008).

Hazard potential depends on topography and roughness (terrain types). Both are also used to establish 2D wave model by combining them with earthquake magnitude scenarios. Topography is determined by considering altitude and the distance from the shoreline. Terrain types are based on landform and land cover. Terrain types are also used to decide the roughness index.

Terrain properties excluding topography affect the inundation zone of tsunami on relatively flat area. It is represented as 'roughness coefficient', or 'n-value', which is related to the inundation distance. In his research, n-value ranges between 0.015 and 0.07 (Hills and Mader, 1997; NERC, 2000; Alpar et al, 2004). The roughness coefficient points out the capability of specified obstacles in reducing tsunami wave penetration, however, tsunami effect is very complicated and is not easily quantified (NERC, 2000). The smallest roughness coefficient value, the larger inundation distance area. The value of 0.015 in his research considering terrain type with open fields without crops, mudflat, ice, spit, coastal plain swamp/backswamp, floodplain, and alluvial plain Mardiatno (2008).

As in Appendix 4, Pacitan sub-district landform consist of marine, fluvial, denudational, volcanic and solutional. In marine landform that distributed in south part of Pacitan sub-district including beach, beachridge-swale, swale, spit, mudflat, ex-beachridge, and backswamp. This landfom contain sand from Grindulu River that deposited by marine process. Fluvial landform distributed in the upper part (north side) from marine landform including alluvial plan, floodplan, natural levee, river terrace and abandoned valey. Most parts of this unit are flat and controlled by Grindulu River and its branches as well as Teleng River (Mardiatno, 2008a). From this landform condition in flat area, Pacitan sub-district tend to create the tsunami inundation with large area.

Mardiatno (2008a) used 810 m, 270 m, 90 m, and 30 m grid sizes in defining grid row and column as parameter in TUNAMI program. Bathymetry data that was derived from direct field measurement was used in this modelling. Three inundation models to determine tsunami hazard potential, i.e. (1) based on elevation (called as simple model); (2) based on terrain roughness coefficients, and (3) based on 2D tsunami wave inundation model (TUNAMI) variables have been included in the calculation. A simple model can be applied for tsunami hazard potential mainly when data on farthest tsunami inundation is not available. In this model, the attention is provided only to inundation possibility under definite elevations without considering tsunami source and propagation factors, such as earthquake and hydrodynamic model. Contour lines of 1 meter are used for references, acquired by a direct field measurement and further processed in GIS. A roughness coefficient-based model provides a simple way of creating a scenario. This model allows the generation of various scenarios (maximum and minimum) of inundation distance using variety of wave heights (in this research Ho=5m, Ho=9m and Ho=12m). It does not require run-up height data prior to it application, thus it is easier in application, particularly for the area where historical data on tsunami is unavailable. Tsunami wave model using TUNAMI provides a complete analysis of hazard potential, i.e. from the initial condition, tsunami propagation and inundation. Based on a hypothetic epicentre location (110.0ºE ; -9.5ºS) and earthquake magnitudes (Mw= 7.5 ; 8 and 8.5). The illustration of initial condition of tsunami using fault model for earthquake Mw=8.5 shown on figure 3.3. with the result 3m as the highest Sea Surface Height (SSH). The red circle show the location of Pacitan area.

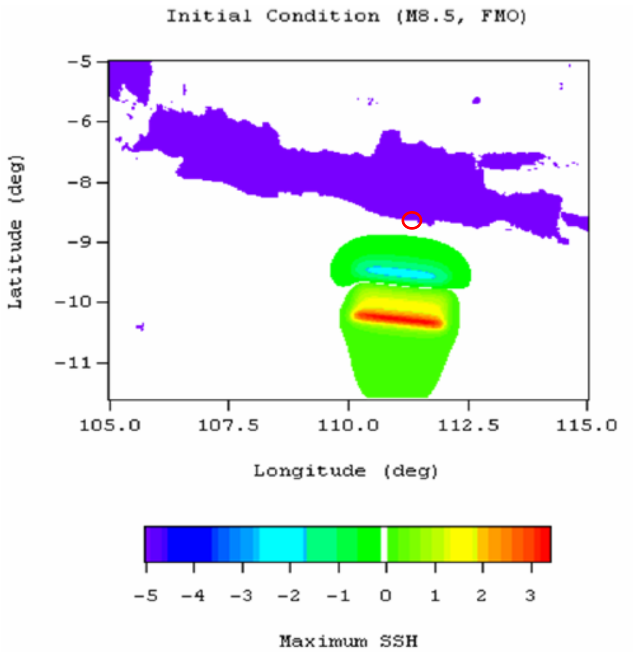


Figure 3.3. Initial condition using fault model scenarios (Mw=8.5) for Pacitan
Source : Mardiatno (2008a)

Approximately 90% of the Indonesian tsunami events are caused by a bottom uplift fault mechanism, and 10% are generated by volcanic eruptions and landslides (Behrens, 2008). In this research the scenario is used with a Mw=8.5 as the worst case scenario. Mw=8.5 is defined for scenario that using earthquake source with magnitude of 8.5 Mw as data source for TUNAMI model and the result shown in Appendix 5 (Mardiatno ,2008a).

Tsunami hazard potential was proceed by georeferencing and digitizing with ArcGIS software. Tsunami potential hazard with flow depth more than 2 m, was overlayed with the maximum flow depth result from earthquake scenario 8.5 Mw as in Appendix 6. The final tsunami hazard potential with earthquake scenario Mw=8.5 in study area (Sidoharjo, Ploso and Kembang villages) by Mardiatno (2008a) shown on the figure 3.4.. The result show that study area dominated by hazard potential with flow depth height 3 - 4 m present as an area with yellow colour that cover more than 50% of study area.

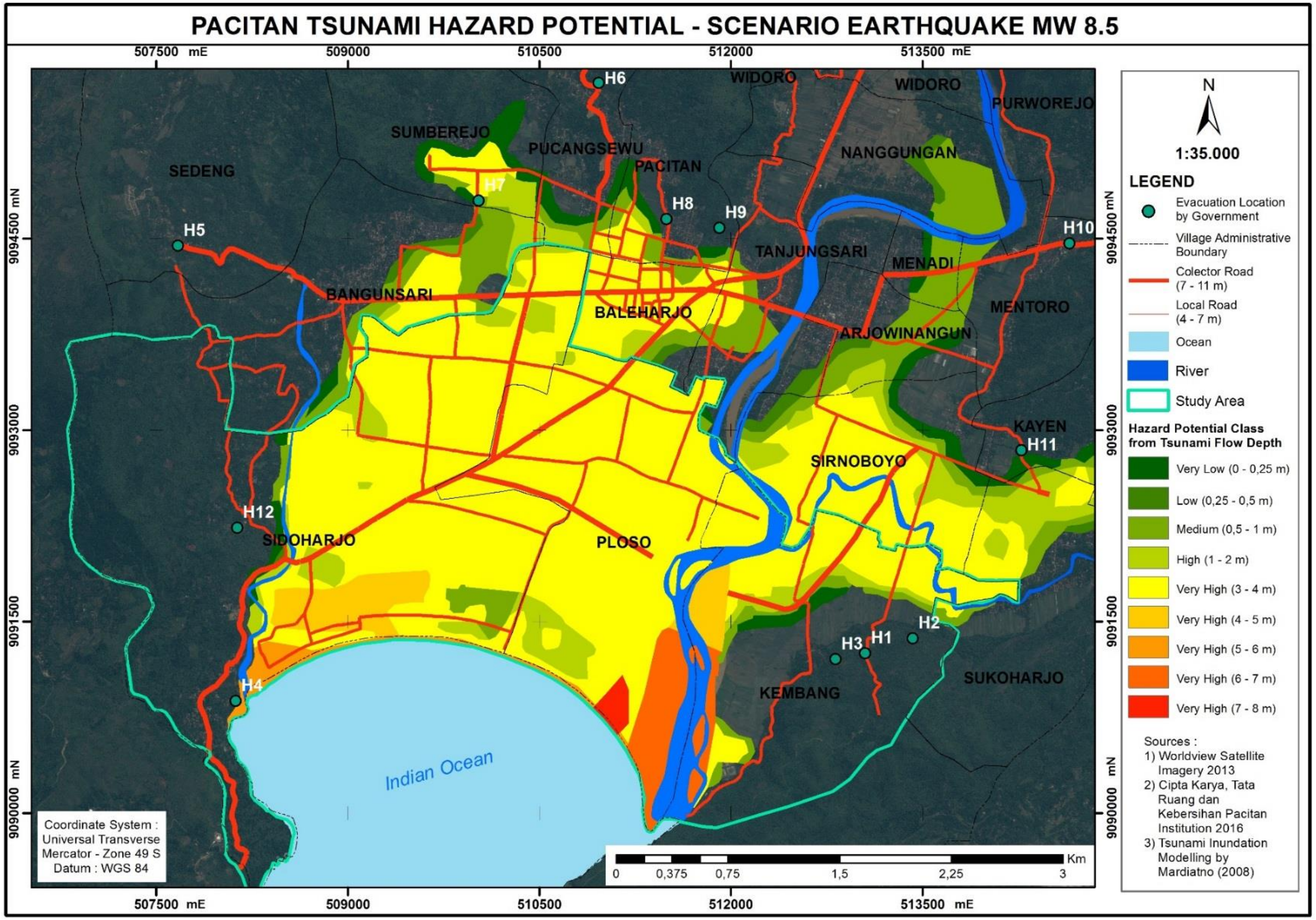


Figure 3.4 Tsunami Hazard Potential-Earthquake Scenario Mw=8.5

Source : Mardiatno (2008a)

As can be seen in figure 3.4., tsunami hazard zonation was overlayed with horizontal shelter location that set by government with code H1 until H12 on the map. It can be seen that the distribution of those shelter are outside inundation area.

Related to tsunami potential hazard in Pacitan, government proposed “20 formula” as can be seen in figure 3.5. This formula means that when earthquake occure with duration more than 20 second, people have time about 20 minute to evacuate theirself to the safe place with minimum elevation about 20 m.

Figure 3.5. Pacitan 20 Formula For Educational Socialization in Pacitan

4.1 RESEARCH DESIGN

The main purpose of this research is to determine the most suitable tsunami evacuation building locations and evacuation routes based on population dynamic in day and night time and considering human behavior in disaster evacuation in Pacitan sub-district area. The research framework on the figure 4.1, consist of pre fieldwork, fieldwork and data processing part. Pre fieldwork consist of data availability, literature study for determining tsunami evacuation building criteria and data processing before fieldwork like image interpretation, and 3D analysis. Fieldwork describe the methodology that is applied in assessing additional data, including building use verification, human speed test, tourist

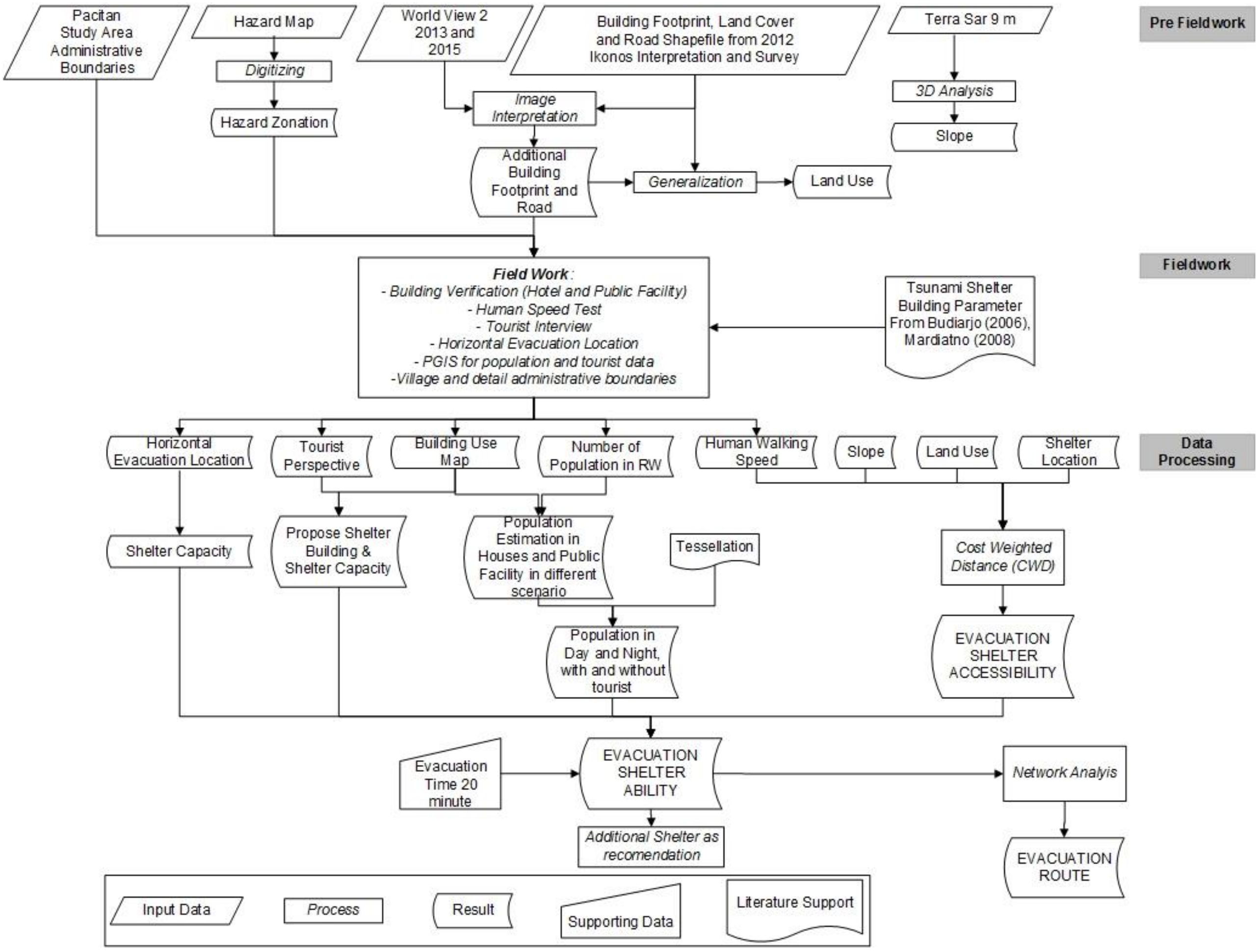


Figure 4.1. Research Framework

interview, neighbourhood (RW) administrative boundaries validation and population in neighbourhood (RW) administrative assessment. Data processing describe method that is applied in shelter capacity estimation, population estimation in day and night, evacuation shelter accessibility and ability, and defining evacuation route.

4.2 PRE FIELDWORK

4.2.1 Data Availability

Data which were used in this research are shown on table 4.1. The data were collected in preparation phase and during fieldwork, including images, maps, shapefile data, and population data. These data used to create input map in this research, like slope and landuse map.

Table 4.1. List of Data Used

<table>
<tr><th>Data</th><th>Description</th><th>Format</th><th>Purpose</th><th>Source</th></tr>
<tr><td>Tsunami Hazard Potential based on flow depth classification</td><td>Based on TUNAMI model on earthquake scenario with Mw=8.5</td><td>Figure (jpg)</td><td>Inundation and safe areas identification</td><td>(Mardiatno, 2008a)</td></tr>
<tr><td>World View 2 Imagery 28 April 2013 and World View 3 3 August 2015</td><td>Multispectral (2 m) and Panchromatic (0.5 m)</td><td>Raster</td><td>Adding Building footprint and road network data</td><td>Indonesian National Institute of Aeronautics and Space (LAPAN)</td></tr>
<tr><td>TerraSar DEM</td><td>Spatial Resolution : 9m</td><td>Raster</td><td>Slope Extraction</td><td rowspan="3">Cipta Karya, Tata Ruang dan Kebersihan Institution</td></tr>
<tr><td>Building and land cover data</td><td rowspan="2">Based on 2012 Ikonos Imagery Interpretation and Field observation on 2016</td><td>Vector</td><td>Building and road detection, Propose vertical evacuation building</td></tr>
<tr><td>Road network</td><td>Vector</td><td>Road classification</td></tr>
<tr><td>Population</td><td>Population number in village level 2015</td><td>Table</td><td>Population distribution</td><td>Village officer</td></tr>
</table>

4.2.2 Image Interpretation

Worldview 2 Imagery 28 April 2013 and Worldview 3 Imagery 3 August 2015 data are needed to augment existing building and road network data. Those imageries were already corrected (radiometric and geometric) from LAPAN institution. The difference date was applied because there are part of information needed from Worldview 3 imagery 2015 that covered by cloud. Therefore, to complete the missing area covering by cloud, Worldview 2 Imagery 2013 was used. In this research, the existing land cover and additional building and road data was used to generalized land use in Pacitan. Road network data was classifed based on table 4.2.

Table 4.2. Road Classification

No	Road Width (meter)	Road Classes
1	≤ 1.5	Pathway
2	1.5 < x ≤ 4	Other Road
3	4 < x ≤ 7	Local Road
4	7 < x ≤ 11	Collector Road
5	> 11	Arterical Road

(Source : PP 43/1993 in Widyaningrum, 2009)

4.2.3 3D Analysis (Slope)

The slope steepness is classified using Digital Elevation Model (TerraSar) data with 9m spatial resolution. Referred to figure 4.1., "Slope" tools on ArcGIS was used to create slope in raster format. This result then was used, as the input data for reclassification using classification from ADPC (2007) on table 4.3.. This slope classification category will be used on cost weighted distance (CWD) modelling in case inverse speed in slope class.

Table 4.3. Slope Values for CWD modelling

Slope (%)	**0-3**	**3-6**	**6-9**	**9-12**	**12-15**	**15-18**	**18-21**	**21-24**
Value (%)	100	85	70	55	45	40	35	30
Slope (%)	**24-27**	**27-30**	**30-33**	**33-36**	**36-39**	**39-42**	**42-45**	**> 45**
Value (%)	25	20	15	14	13	12	11	10

Source : (ADPC, 2007)

4.3 FIELD WORK

4.3.1 Horizontal Evacuation Validation

Pacitan government already set 12 locations in surrounding Pacitan City for tsunami horizontal shelter location. The method that is used in this part is survey method, by visiting all the shelter location based on the location information from Pacitan government.

4.3.2 Evacuation Building Validation

Referred to figure 4.1., evacuation building (vertical building) validation in this part was divided into 2, hotel building validation and public facility validation. The method in this part was census method by check one by one location of the building and hotel based on the existing data from Cipta Karya, Tata Ruang, dan Kebersihan institution and tourism institution.

4.3.3 Determination of Proposed Evacuation Building

Due to the limitation tsunami hazard result that only considering flow depth, in this research, the propose evacuation building was referred from building criteria from Budiarjo (2006), Mardiatno (2008a) on sub part 2.4. and human perspective in disaster evacuation. Interview method was used to assess human perspective in disaster evacuation applied in tourism area (Pancer Door beach and Teleng Ria beach) based on list question on the Appendix 7. The expected human behaviour during disaster characteristic referred to explanation from Murosak, 1993 on Huang & Wu, (2011).

There are 6 expected human behavior in disaster evacuation. Homing behavior is when people encounter a disaster, they choose the most familiar paths and location for escape. Avoidance behavior is when people encounter a disaster, they move away from a fire or other danger. Phototropism is when people encounter a disaster, they move towards bright place because they think that is likely to be a safe place. Conformity behavior is when people encounter a disaster they feel nervous and will be impaired in making decision independently and so most people would follow the crowd. Straight characteristic is when people encounter a disaster, they choose the straight route becuase the complicated route is perceived as more dangerous. Openness characteristic is when people encounter a disaster, they move towards more spacious place because they believe being in a more open space would help them avoid any secondary damage. Proximal characteristic is when people encounter disaster, they choose the closest route or stairs to evacuate in order to save time (Murosak, 1993 on Huang & Wu, 2011).

Building characteristic assessment was conducted by scoring method including 4 main parameters as can be seen on table 4.4. including distance from shore, distance from river, number of floors, and building location elevation. Distance from shore should be at least 200 m from shore line based on the survived building after Indian Ocean tsunami on 26 December 2004 (Budiarjo, 2006). Distance measurements of the building against the coastline was conducted by using “Measure” tools in ArcGIS. Line distance measurement between buildings with a coastline was conditioned perpendicular with coastline. The same concept was applied for distance from river. It is assumed that the minimum safe building from river is the same with distance from shore, at least 200 m, because basicly river possible to be entered by tsunami wave and can bring material in the form such as the ruins of the house and trees that affected by the tsunami. Building location elevation was assesed based on overlaying contour data that derived from Terrasar 9m with building location. Building elevation should be at least located in 10 m asl because based on tsunami flow depth result on figure 3.4. from Mardiatno (2008a), Pacitan was dominated with flow depth 3 – 4 m. In that case, if there is a building in 10 masl consist of 2 floors, the second floor still can be allocated for evacuation because the first floor building height is between 3 until 4 m. Number of floors were assessed based on field work.

For the building scoring system, scores only present the relative comparison. 0 is given for building parameter that extremely vulnerable will be destroyed by tsunami if a building with that category is choosed as propose evacuation. In reverse, scoring system 3 is given for building parameter that will not vulnerable to be destroyed by tsunami. While for scoring system in between

0 and 3 are given for parameter that are in the medium level of vulnerability.

Table 4.4. Building Assessment Scoring System

Distance from Shore (m)	Distance from River (m)	Elevation (masl)	Number of Floor	Score
0 – 200	0 – 200	<10	1	0
200 – 1000	200 – 1000	10	2	1
1000 – 2000	1000 – 2000	15	3	2
>2000	>2000	30	>3	3

(Source : Data Analysis, 2016)

However, before apply those scoring parameter, the propose building was sorted based on building construction on table 4.5. and building orientation that should be parallel with wave direction and number of floors that should be more than 1. Building construction should be at least at the medium category. At the end, the propose building shleter was choosed based on the highest total score as the priority by determining building that is located along the main road as consideration of human behaviour in disaster evacuation .

Table 4.5. Classification of Building Construction

Category	Building Strength	Building Types	Explanation
High	Weak	Partly permanent; moderate	Wall using bricks partly, fieldstone, wood, bamboo, unreinforced, crumbling and/or deserted
Medium	Medium	Partly permanent;good Permanent;moderate	Building bricks partly and/or whole, cement mortar, no reinforcement
Low	Strong	Permanent;good	Building bricks, pre-cast concrete skeleton, reinforced concrete

Source : Mardiatno (2008a)

4.3.4 Population Validation

Population validation in this part was divided into three parts:

1. Administrative validation using Participatory GIS method to know the number of population in each neighborhood (RW level). Moreover, the

existing adminsitrative boundaries from Cipta Karya, Tata Ruang dan Kebersihan institution was clarified also using Participatory GIS method.

2. Hotel and Homestay validation using Participatory GIS method to know the hotel and homestay capacity.
3. Public Facility validation using Participatory GIS method to know the number of population in each public facility, in this research focus on educational facility with multi storeys building

4.3.5 Human Speed Test

Human speed test was conducted by using simple random method to test the tourist walking speed based on different age category from Indonesian Health Department (2009) classification using at least one person as an example. This method was applied in tourism area. Age category including Toddler (0-5 years old), Childhood (5-11), Juvenile-Early (12-16), Juvenile-End (17-25), Adult-Early (26-35), Adult-End (36-45), Elderly-Early (46-55), Elderly-End (56-65) and Over Age (more than 65). People were asked to walking with average distance of 14 m and range between 7 until 25 m, with stopwatch on to know how long that they need to walking in certain distance. The test was conducted in all age group and gender, except for toddler between 0 until 5 years. It is assumed that toddler always together with their parents.

4.4 DATA PROCESSING

4.4.1 Shelter Capacity Estimation

Referred to figure 4.1., shelter capacity estimation was calculated for horizontal evacuation and propose shelter building. Therefore, shelter capacity (TEBC) was calculated by using the formula Widyaningrum (2009):

TEBC={(Capacity Score*Building Area*Amount of Floor)/ Space 1 person)

Here :

- Refers to BAPPEDA (Indonesian National Development Agency), the space for one person is $1m^2$ (0,8 m^2 for standing and 0,2 m^2 for circulation)
- The capacity score depend on the type of building on table 4.6.

Table 4.6. Building Capacity

No	Type of Building	Available Capacity = Capacity Score * Area
1	Hall/Galery	100% * Building Area
2	Mosque/Worship	78% * Building Area
3	School	30% * Building Area
4	Hotel	26,3% * Building Area
5	Office	23.6% * Building Area
6	Mall/Market	23% * Building Area

(Source : Budiarjo, 2006 ; Widyaningrum, 2009 ; Dewi, 2010)

Hall or gallery design is assumed to free from equipment, furniture and other things. In that case, 100% of hall area can be allocated for evacuation.

Space for mosque design is 1.8 m^2/person with 1.2 m^2/person for praying, 0.2 m^2/person for circulation and 0.4 m^2/person for utilities and other supporting facilities. The space that can be occupied for evacuation are praying and circulation area (1.4/1.8=78% area). Therefore, 78% of total mosque building area can be allocated for evacuation (Budiarjo, 2006).

School building is assumed consist of furniture and equipment with approximately 70 % of total area. Therefore, 30% of school building can be allocated for evacuation (Budiarjo, 2006).

Space for hotel design is 16 m^2/person with 12 m^2/person for staying and 1.5 m^2/person for circulation; 0.5 m^2/person for utilities; 1.5 m^2/person for hall, lobby and restaurant (public function); 0.3 m^2/person for employees' room; and 0.2 m^2/person for office function. From this space requirement, the space that can be occupied for evacuation are circulation (1.5/16 =9.4% area), public function (1.5/16 =9.4% area) and assumed 10% non occupied rooms (0.1*1.5/16 =7.5% area). Therefore, 26.3% of total hotel building area can be allocated for evacuation (Budiarjo, 2006).

Space for office design is 8.5 m^2/person with 4 m^2/person for working (Neufert, 1997); 1 m^2/person for meeting room; 1 m^2/person for circulation, lobby and foyer; 0.5 m^2/person for rest area and utilities; 1 m^2/person for hall and 1 m^2/person for archieve and equipment room. The space that can be occupied for evacuation are circulation, lobby, and foyer area (1/8.5=11.8%

area) and hall area (1/8.5=11.8% area). Therefore, 23.6% of total office building area can be allocated for evacuation (Budiarjo, 2006).

Space for market design is 5.2 m^2/person with 1 m^2/person for buyer; 0.2 m^2/person for circulation; 2 m^2/person for seller and merchant display; and 2 m^2/person for storage. The space that can be occupied for evacuation are buyer and circulation area (1.2/5.2=23% area). Therefore, 23 % of total market building area can be allocated for evacuation (Budiarjo, 2006).

4.4.2 Population Modelling

Population estimation analysis based on land use category required more time in case of data collection. Due to the needed to get the detail data in each neighbourhood (RW) for example about number of people based on job category, to estimate the distribution of people in different land use and different scenarios. Therefore, this method will suitable to be applied in areas with complete detail data inventory. In this research, the collecting number of update people based on age category in RW level is pretty hard. Thus, in this study, the population estimation only focus on building use by using the approach of the population, the number of households, and the number of houses in each RW.

In this research population modelling was conducted by using tessellation method to cocentrate number of people in the point location. A tessellation provide a way to deal with space occupancy. There are two kind of tessellation, irregular and regular. Irregular are used in areas like zonal for social, economic, demographic and administrative data. Regular are benefit in image data remote sensing. (Laurini and Thompson, 1992 on Dewi, 2010). Hexagonal tessellation was generated using an ArcGIS extension from Whiteaker (2015). The steps including :

a. Setting the area interest (Sidoharjo, Ploso and Kembang villages).
b. Create hexagonal tessellation by set length parameter (100 m in this research).
c. Overlaying the tessellation result with building maps, and delete some tessellation that does not consist of building.

d. Create a center point in each tessellation with "X Coordinate of Centroid" and "Y Coordinate of Centroid" from "Calculate Geometry" tools in ArcGIS.
e. Calculate the number of population in each point tessellation in different scenario (day without touris, day with tourist, night without tourist, and night with tourist) and put this information on center point atribute table.

Each tessellation consist of different number of house and public facility. In order to estimate population in day and night scenario, population estimation divided into 2 part, including :

1. Population estimation in the house

The number of occupant in each RW, the number of household in each RW and clarifying the number of houses based on building data are the result of field data that will be used in estimating the population in each house. Population estimation in the house was done by using the following formula (Dewi, 2010). Based on field work data, we can estimate the number of household per house building and the occupant per building.

HsPH = HPR / BPR

OPB = HsPH x OPH

<u>**Here :**</u>

HsPH = Number of household per house

HPR = Number of houses per RW

BPR = Number of buildings per RW

OPB = Number of occupants per building

OPHs = Number of occupants per household

In day and night time, the population distribution in define area will be different. In day time, it was assumed that 50% of the occupants were at home, and the rest were outside for their activity. As an example, if 1 family consist of four people (father, mother, and two children), the mother and youngest child stay at home during the day and the father working and the oldest child studying at school. In night time, it was assumed that all of people are at home. However, this 50% values is only assumption and needs further research of existing data related the number of people that stay at home during day and number of people at work, school etc in that study area. The calculation of population in the tessellation is by calculating the number of houses per tessellation and multiplying the result with the number of occupant per houses. For each tessellation, the population in day and night time were calculated using the following formula (Budiarjo, 2006, Dewi, 2010) :

Day-time = 50% number of houses * number occupants/house

Night-time = 100% number of houses * number occupants/house

2. **Population estimation in the facilities**

Population in the facilities are derived from fieldwork result data that in this research including the number of student in multistoreys school and room capacity in hotel to estimate the possible number of hotel visitor. For other public facility, due to limitation time to get the data, the population estimation can be done by using the formula from table 4.7.

Table 4.7. Public Facility Estimation

Mosque	
Day scenario	10% (capacity) * building area / 1.8 (space requirement)
Night scenario	1 person Only one security guard is available during the night
School	
Day scenario	110% (capacity) * building area / 4 (space requirement) or 110% (capacity) * number of occupants 10 % for other occupants i.e. teacher, officer, food & seller
Night scenario	1 person
Boarding House	
Day scenario	1 person
Night scenario	100% (capacity) * building area / 4.6 (space requirement) It is assumed only 2 person stay at the building (cleaning service and security)
Office	
Day scenario	100% (capacity) * building area / 8.5 (space requirement)
Night scenario	1 person
Shop	
Day scenario	4 person (employee and/or visitor)
Night scenario	1 person
Ruko (shop & house)	
Day scenario	50% (familiy member) * population/household) + 4 (employee and/or visitor)

Night scenario	100% (family member) * population/household
Hotel	
Day scenario	50% (capacity) * building area / 16 (space requirement)
Night scenario	80% (capacity) * building area / 16 (space requirement)
Factory	
Day scenario	Total people in the whole facility area It is assumed that the area contain its regular occupant Based on field observation, estimation is conducted by knowing the number of people in factory (workers, security, cleaning service, etc)
Night scenario	2 person (security guard)
Fish Market	
Day scenario	Total people in the whole facility area It is assumed that the area contain its regular occupant Based on field observation, estimation is conducted by knowing the number of people in factory (workers, security, cleaning service, etc)
Night scenario	2 person (security guard)

(Source : Budiarjo, 2006, Dewi, 2010)

In this study area, the existing public facility consist of mosque, office, shop, school and hotel. Therefore, the formula was applied only for mosque, office, shop, and school. In mosque, the day scenario time is around the preparation of Zhuhur prayer (12.30 – 13.00), such that the facility is filled at its 10% capacity. In office, it is assumed that in the day scenario the building containts its regular occupants (100% capacity). In shop, it is assumed that in the day consist of average regular occupants of 4 person include the employee(s) and visitors. In school it is assumed that in day scenario will consist of regular occupants (100% capacity) and other occupants like teacher, officer, food and merchandise seller that assumed to be 10% of the student, such that the total occupants is 110% of students number. In night time, it is assumed that only 1 person of security and cleaning service that stay at those public facility. (Budiarjo, 2006).

4.4.3 Evacuation Shelter Accessibility and Ability

In this research evacuation shelter accessibility was conducted by using cost weighted distance (CWD) method (ADPC ,2006). CWD method using speed value of landuse, speed value of slope, shelter location and average human walking speed to create catchment area (basin) in each shelter location with information about evacuation time. Speed value of landuse as on the table 4.8. was used to get the new human walking speed in different landuse category. As an example human walking speed in road is 100% from average human walking speed that means in this type of landuse people can walking in their maximum speed of walking. In different landuse, human walking speed in river is only 1 % from average human walking speed that meens in this landuse people can not walking with maximum speed. Speed value for slope classification on table 4.3. was also used to represent how much the speed will change on the different slope category.

Each catchment area then was overlayed with tessellation that already consist the information about population in day and night with and without tourist scenario. The visualization of those data, and shelter capacity estimation were used to know the evacuation ability in each shelter in different scenario.

Table 4.8. Landuse Values

Landuse	Value (%)	Landuse	Value (%)
River Channel/Pond	1	Rubber Trees	55
Lakes and Wetlands	2	Open Vegetation	60
Fishing Pools	3	Coconut Tree	65
Building	5	Beach	70
High Grass/Rice Field	40	Open Field	80
Dense Vegetation	50	Roads	100

Source : (ADPC, 2007 with modification)

4.4.4 Evacuation Route

Evacuation route was proceed by using network analysis method in each catchment area (basin). There are 5 types of network analysis. In this research, 2 of them are compared in this route modelling to finding the suitable routing method, including comparison for finding the best route and finding the closest facility layers. To define evacuation route, the first thing that need to do is creating network dataset in ArcGIS, with the steps including :

1. Prepare input dataset (road, shelter, tessellation).
2. For the road dataset, the table atribute should include information related

with time impedance by considering walking speed and road width. Atribute name of FT_MINUTES and TF_MINUTES (FT refers to From To and TF refers to To From, it is based on the direction of traffic flow) was defined since impedance values will be different in different directions. In Pacitan, time impedance are the same because all of road are two way (permit travel in either direction).

Knoblauch (1996) in Dewi (2010) described that walking rates are influenced by a variety parameter like road width, road density, pedestrian number in a group, etc. In this research, walking rates was defined based on road width classification. Walking speed on road was calculated using :

C0 = W/S

C1 = W/S

V = (C0/C1)*Vs

Here:

V = Actual speed of walking during disaster (m/s)

C0 = Base capacity of the road (round-in value)

C1 = Actual capacity of the road during disaster (round-up value)

Vs = Speed of walking, in this research using walking speed test result 0.936 m/s

W = Road width (m)

S = Space requirement of person 0.625 sq meter (Neufert,1999)

The calculation result of speed walking shown on the following table 4.9.

Table 4.9. Walking Speed Calculation

No	Road Width	Base Capacity (C0)	Actual Capacity (C1)	Actual Speed (Vs) in m/s
1	1.5 m	=1.5/0.625 = 2.4 =2	=1.5/0.625 = 2.4 =3	=2/3*0.936 =0.47
2	4 m	=4/0.625 = 6.4 =6	=4/0.625 = 6.4 =7	=6/7*0.936 =0.80
3	7 m	=7/0.625 = 11.2 =11	=7/0.625 = 11.2 =12	=11/12*0.936 =0.86
4	11 m	=11/0.625 = 17.6 =17	=11/0.625 = 17.6 =18	=17/18*0.936 =0.88

3. Create network dataset by set up dataset name and network source (road). In this research did not including turn becuase the data were not available.
4. Build network dataset as default process after create network dataset.

5.1 SLOPE

The slope steepness is classified using Digital Elevation Model (TerraSar) data with 9m spatial resolution using classification from ADPC (2007) on table 4.3.. As can be seen on figure 5.1., Pacitan sub-district is mainly flat area with slope percentage from 0% until 3 %. The surrounding of this flat area is consist of hilly area with slope percentage more than 6 %. Related to slope values for CWD modelling on table 4.3, the bigger number of slope percentage, the lower new slope value, indicating that human walking speed reduce much more in the steep topography. From figure 5.1., the topography condition in study area (Sidoharjo, Ploso and Kembang villages) are dominated by slope 0-3% that will have a new slope values of 100% from average human walking speed.

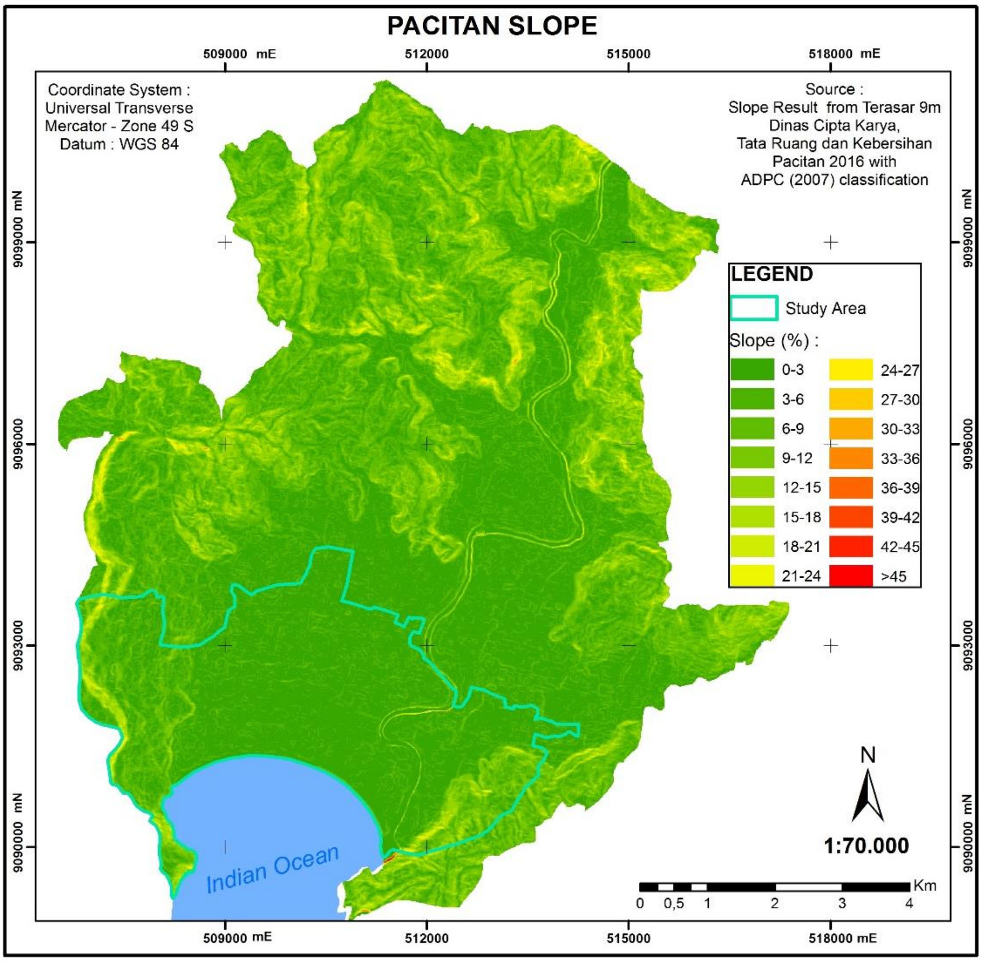


Figure. 5.1. Slope in Study Area

5.2 LAND USE

The existing land cover and additional building and road data from image interpreation was used to generalized land use in Pacitan using classification from ADPC (2007). Building land use type was derived from settlement, industry, warehouse, office, shop, mosque, museum, education building, church, market, and hotel and homestay land cover type. Dense vegetation land use type was derived from production forest and forest land cover type. Open vegetation land use type was derived from miced garden, garden, moor and shrub land cover type. Land use map in Pacitan was present on the figure 3.2.

5.3 SHELTER LOCATION

5.3.1 Horizontal Evacuation Location

Pacitan government set 12 tsunami horizontal shelters location in surrounding Pacitan sub-district. As shown on figure 5.2., most of them are located in hilly topography and open field area. The figure of shelter in left and right side of map was conducted during fieldwork. The main concept of Pacitan government is to define the temporary location for people to save their life. Temporary shelter is an area that is not flooded or impacted by tsunami inundation in suitable landuse, such as open field area. The area is used for short-term period of evacuation (1-2 days) to escape fastly from the impact of tsunami waves (Widyaningrum, 2009). Pacitan government set signboards for evacuation signage and shelter location as shown in figure 5.3. Figure 5.3. (left) present an example of evacuation sign to go to “Puncak Giri Sampurno” or shelter ID H9 on figure 5.2 that need distance about 540 m more from that location. Government put this sign in every crossroad to make sure people know where to go when they need to evacuate. Figure 5.3 (right) present the example of evacuation signage for “Puncak Giri Sampurno” shelter location. Tsunami shelter capacity was calculated by using Widyaningrum (2009) formula. Horizontal shelter is an open field area, therefore the capacity score for shelter calculation in this research is 100 %.

Tsunami Evacuation Building Capacity (TEBC) = {(100%* Area)/1m^2}

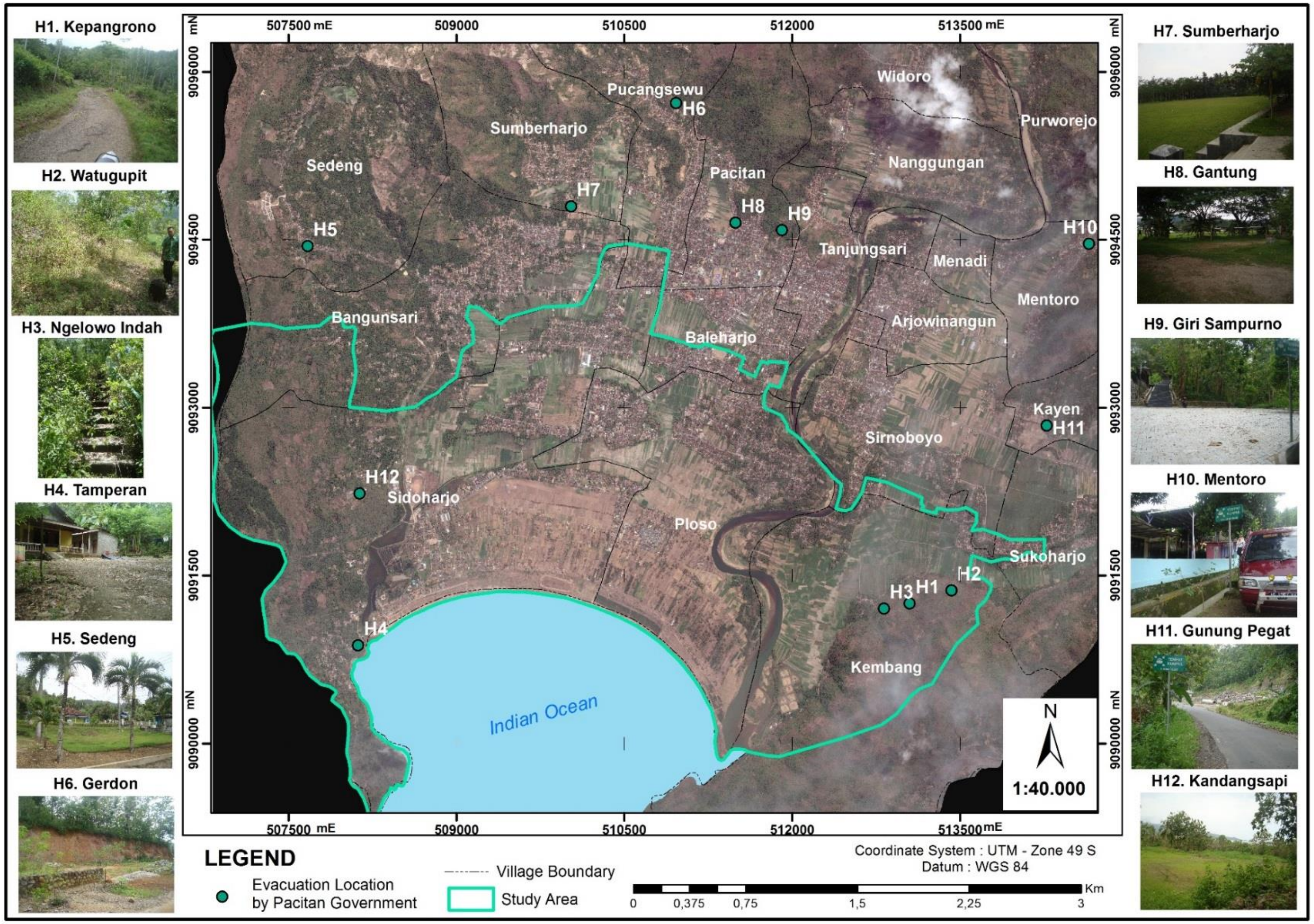


Figure 5.2. Horizontal Evacuation Location Set By Pacitan Government
(Source : Fieldwork, 2016)

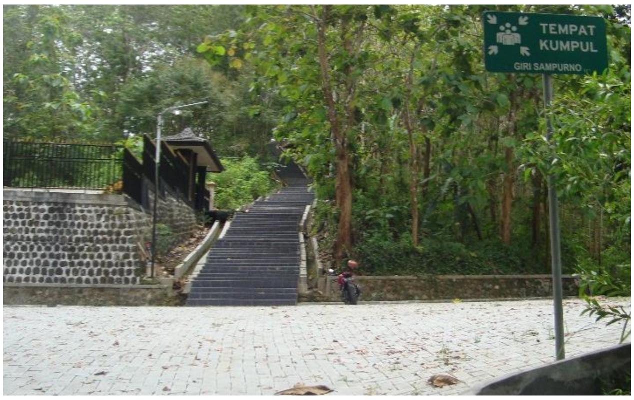


Figure 5.3. (Left) Evacuation Sign ; (Right) Evacuation Signage
(Source : Fieldwork, 2016)

Based on calculation result on table 5.1., the largest shelter that can accomodate a lot of people are Shelter Sumberharjo and Shelter Kandangsapi.

Table 5.1. Horizontal Evacuation Capacity

ID	Name	Total Area m^2	TEBC	ID	Name	Total Area m^2	TEBC
H1	Kepangrono	647	647	**H7**	Sumberharjo	10937	10937
H2	Watugupit	120	120	**H8**	Mentoro	463	463
H3	Ngelowo Indah	120	120	**H9**	Giri Sampurno	573	573
H4	Tamperan	168	168	**H10**	Gantung	563	563
H5	Sedeng	730	730	**H11**	Gunung Pegat	706	706
H6	Gerdon	1060	1060	**H12**	Kandangsapi	7174	7174

(Source : Data Analysis, 2016)

5.3.2 Human Perspective in Disaster Evacuation

Pacitan has never experienced a tsunami in the past (Latief et al, 2000 in Mardiatno, 2008a). In this research, interview using simple random method was used to know the tourist perspective about tsunami and disaster evacuation. The number of tourist will vary from time to time. Thus, in this study the number of tourists interviewed were not specified. The number of respondents deemed to be sufficient if the answers of respondents has shown a pattern and the same result. The interview was conducted in Teleng Ria beach and Pancer Door beach on 22 October 2016, 25 December 2016, 31

December 2016 and 1 January 2017. Total respondent in Teleng Ria beach is 72 people and 15 people in Pancer Door beach. Interview result in Pancer Door beach present in Appendix 8., and Appendix 9. for Teleng Ria beach.

Tourist domination in Teleng Ria beach based on information in Appendix 10 is domestic, and in Pancer Door beach there are some foreign tourist that come for surfing. The explanation of this interview result, including:

1. **Respondent Age Group**

Respondent age group information in Appendix 8 and 9 in this research, shown on the following table 5.2. Adult and elderly category from Indonesian Health Department (2009) is in the age between 26 until 65 years old. Based on table 5.2. 55.5% of respondent in Teleng Ria beach and 66.6% of respondent in Pancer Door beach are adult and elderly category. Moreover, the respondent gender in this research was dominated by women.

Table 5.2. Respondent Age Group

Age Group	Teleng Ria Beach	Pancer Door Beach	Age Group	Teleng Ria Beach	Pancer Door Beach
11 - 15	6	-	41 - 45	5	1
16 - 20	20	-	46 - 50	6	1
21 -25	5	5	51 - 55	5	3
26 -30	1	2	56 - 60	1	-
31 -35	6	3	71 - 75	1	-
36 -40	16	-			

(Source : Fieldwork, 2016)

2. **Knowledge About Disaster**

Fifty three from 72 respondent in Teleng Ria beach, or 73.61 % respondent did not know anything related to tsunami potential hazard in Pacitan sub-district. This result can be supported because mostly, tourist come from district area that do not facing ocean. Moreover, 86.11% respondent did not see any tsunami evacuation sign along the road to Teleng Ria beach. Based on Appendix 9, 13 from 19 respondent or 68.4 % respondent that know Pacitan is potential for tsunami, visiting Pacitan for more than 1 time. While, 7 from 10 respondent or 70% respondent that see evacuation sign along the road to Teleng Ria beach, also visiting Pacitan for more than 1 time. In Pancer Door beach, 9 from 15 respondent already know about potential hazard and evacuation sign in Pacitan, with 6 people (67 % respondent) that visiting this place more than 1 time. It can be concluded that the intensity of people to visit tourism place relate to the increasing understanding about potential hazard in that area. This condition can happen because when they visiting tourism location, there are a probabilty for them to interact with local people that mostly understand about the potential hazard in they area based on socialization program from government.

3. Knowledge About Evacuation Time

Twenty five from 72 respondent in Teleng Ria beach, or 34.72 % respondent already knew that they have a limited time to evacuate theirself. However 37 from 72 respondent, or 51.39 % still did not know anything related the time that they have to evacuate when tsunami occur. Even in Pancer Door beach, 73% of repondent also did not know the time they needed to evacuate. The rest of respondent said that they need to evacuate in more than 20 minutes.

When compared with local people perspective in Pacitan, related to evacuation time Mardiatno (2008a) also did the interview, with total of 30 respondents. The result show that 74 % of the respondent think to evacuate in the short time (bellow 20 minutes) as soon as possible. 20% respondent think they need to evacuate by time more than 20 minutes, and 6% respondent did not give comment for this question.

The differences percentage of local people and tourist that answer to evacuate bellow 20 minutes show that different origin area will create different perspective. People that live far away from ocean maybe will not have any knowledge related tsunami hazard and evacuation time. In case of people that live adjoining with ocean, socialization and education from government program create their perspective related to potential tsunami hazard in their area and the important of time that they have to evacuate.

4. Knowledge About Tools for Evacuation

Tourist knowledge information about evacuation means in Teleng Ria and

Pancer Door Beach can be seen on the table 5.3. All Teleng Ria beach respondent was domestic tourist. 46 from 72 respondent or 63.89% respondent said that they choose to walk/run as evacuation means. This perspective come up because at the interview time, most of the tourist come by using car or bus together with their family or community to enjoy the holiday. This condition make they think that they did not need to use their valuable things (vehicle) as evacuation means so thats why they choose to run to safe their life. In different location, Pancer Door beach consist of domestic and international tourist. For domestic tourist, 60% respondent said that they will choose to use own private vehicle (motorcycle) as evacuation means. For international tourist, 80% of respondent said that they will choose using motorcycle that they rent in Pacitan as evacuation means.

When compared with local people perspective in Pacitan, related to means for evacuation, Mardiatno (2008a) also did the interview, with total of 30 respondents. The result show that 40 % of the respondent think to evacuate using car, 44% respondent think to evacuate use motorbike, 3% using bike and 13% by running. Moreover, Goto, Fadli, Affan, & Reliability (2012) did the interview to people in Banda Aceh just after the 2012 April 11 of Sumatra Earthquake. The result show that 73.39% of 613 respondent did evacuation using motorbikes. Domination of local respondent that tend to use vehicle for evacuation amplify the explanation from Sutikno, Murakami, & Suharyanto (2010) that residents tend to use their vehicle for evacuation, because car or a motorcycle is one of the expensive belongings. However Goto, Fadli, Affan, & Reliability (2012) also did the interview to people in Banda Aceh just after the 2012 April 11 of Sumatra Earthquake related to evacuation method and traffic jam. The result show that 85.4% of respondent that choose to evacuate using motorbikes, was trapped in a traffic jam at least once. 93.2% of respondent that choose to evacuate using car, was also experienced the same.

Respondent vehicle to go to tourism location can be analyzed for respondent economical background. It can be assumed that respondent that using car (49 from 87 respondent) was classified into respondent that have high income (economical backgorund), because they have car private vehicle that is expensive. People that using motorcycle (21 from 87 respondent) can be classified have middle income (economical background), because they have motorcycle private vehicle that the price is cheaper than car but more expensive than renting bus. At last, people that using bus (12 from 87 respondent) can be classified have low income (economical backround) because there are not using private vehicle, but still can pay for bus rent. Economical background from respondent in this research was dominated by high income economical background.

Table 5.3. Respondent Knowledge About Tools for Evacuation

Tools	**Teleng Ria Beach**		**Pancer Door Beach**			
	Domestic Tourist		**Domestic Tourist**		**International Tourist**	
	Vehicle	Evacuate	Vehicle	Evacuate	Vehicle	Evacuate
Walk/run	-	46	-	4	-	1
Motorcycle	12	6	9	5	-	4
Car	48	14	1	1	-	-
Bus	12	6	-	-	-	-
TOTAL	**72**	**72**	**10**	**10**	**0**	**5**

(Source : Fieldwork, 2016)

5. **Knowledge About Evacuation Method**

59 from 72 respondent in Teleng Ria beach, or 81.94 % respondent think that they will evacuate by looking route based on their own knowledge, while 18.06 % respondent think they didnt have any idea where to go, and just want to follow crowded. In Pancer Door beach, 67 % respondent think they will looking for their own knowledge and 33 % think they need to follow crowded.

6. **Knowledge About Destination to Evacuate**

Tourist knowledge information about the destination they choose to evacuate was mapped on the Appendix 11 and 12. The route in these map was created based on respondent answer about where to go to evacuate. Most of them have the homing behavior. Moreover, it is assumed that tourist as foreigner will visit tourism area by using main road. Main road in Pacitan means collector road. This road type have the classification with width between 7 until 11 m. In that case, private vehicle and mass vehicle like bus can through this road to go to tourism area. Optional route A and B in Appendix 11 are the same with optional route A and B in Appendix 12. Optional route A is defined by tourist that think they want to evacuate by homing behavior to Nganjuk, Ponorogo, Madiun, Magetan, Ngawi, and Bandar. Optional route B is defined by tourist that think they want to evacuate by proximal characteristic. Optional route C in Appendix 11 is defined by tourist that think they want to evacuate by homing behavior to Klaten, another district of Pacitan, Boyolali, Sukoharjo, Sragen, Solo, Karanganyar, Wonogiri, Yogyakarta, Sambungmacan, and Gunungkidul.

Related to these map,. tourist answer about they inclination can be seen on the table 5.4. In Teleng Ria beach 41 from 72 respondent or 56.94% respondent choose the route that leading they back to home, and 5 respondent think they need to go to city center to ask help. Those 46 respondent can be categorized have homing behavior in disaster evacuation, because they think to heading to their familiar place. However 16 respondent or 22.22% respondent choose to run to the nearest hill (the hill in the west part of this beach or optional route B) and this group can be categorized as proximal characteristic in disaster evacuation. In another condition, 10 respondent still confused about where to go and think they just want to follow crowded, this group can be categorized as straight characteristic in disaster evacuation. Based on Appendix 9, 10 from 17 (58.8% respondent) that have proximal characteristic,and 24 from 46 (52.2% respondent) that have homing behavior, visiting Pancer Door beach more than 1 time. It can be seen that people intensity to visit tourism area, relate with the increasing understanding of them in the way they make decision about where to go in evacuation case.

In Pancer Door beach, 3 from 15 respondent or 20 % choose the route that leading they back to home, and 5 respondent think they need to go to city center to ask help. Those 8 respondent or 53.3 % respondent can be categorized have homing behavior in disaster evacuation, because they think to heading to their familiar place. However 6 respondent or 40% respondent choose to run to the nearest hill (the hill in the west part of this beach or optional route B) and this group can be categorized as proximal characteristic in disaster evacuation. Moreover, 1 respondent think to run to her homestay that is multistoreys building to safe her life, and it can be also categorized as proximal characteristic in disaster evacuation. Based in Appendix 8, 3 from 7 respondent that have proximal characteristic,and 7 from 8 respondent that have homing behavior, visiting Pancer Door beach more than 1 time. It can be seen that people intensity to visit tourism area, relate with the increasing understanding of they make decision about where to go in evacuation case.

Table 5.4. Respondent Option About Destination to Evacuate

Route/Destination	Teleng Ria	Route/Destination	Pancer Door
A	41 (56.94%)	A	3 (20%)
C		B	6 (40%)
B	16 (22.22%)	City Center	5 (33.3%)
City Center	5 (6.94%)	Vertical Building	1 (6.7%)
Confused	10 (13.89%)		

(Source : Fieldwork, 2016)

5.3.3 Propose Shelter Building

Vertical evacuation building assessment was conducted by considering criteria from Budiarjo (2006), Mardiatno (2008a) and human perspective in disaster evacuation from section 4.3.3. Interview method was used to assess human perspective in disaster evacuation applied in tourism area (Pancer Door beach and Teleng Ria beach).The propose building was sorted based on building construction from table 4.5. and building orientation that should be parallel with wave direction and number of floors that should be more than 1. Based on fieldwork result, the selected propose building have medium building strength category from table 4.5. Medium category is building with bricks partly and/or whole, cement mortar, no reinforcement.

The propose building that already sorted was assessed using scoring method with 4 main parameters from table 4.4.. The propose building shelter was choosed based on the highest total score for building that located along the main road (evacuation route option in Appendix 11 and 12) as consideration of human behaviour perspective in disaster evacuation. The visualization of propose shelter distribution was mapped in Appendix 13.

1. Hotel Validation

Ten outoff the 21 hotel and homestay result in Appendix 14 were selected based on building construction, building orientation and number of floors parameter from section 4.3.3. These building have the same building construction in medium category with bricks and cement mortar. Scoring table on the Appendix 14 referred to scoring system parameter from section 4.3.3. show that the scoring total result range between 4 until 8. The 3 highest total score was choosed as propose vertical evacuation building. The first highest score is 8, consist of Bali Asri and Srikandi hotel. The second highest score is 7, consist of Graha Prima hotel. The last highest score is 6, consist of Wijaya Hotel, but this hotel located only 71 m from the main river (Grindulu river). In that case, there are only 3 hotel that are proposed as building shelter location, Graha Prima Hotel, Bali Asri and Srikandi Hotel. Based on Appendix 13, Graha Prima hotel presented with ID V2 located outside potential hazard with elevation 30 masl. This building located 671 m from shore, and 78 m from Tamperan river. Graha prima hotel have the unique building concept because set in slope location. The first building is 2 storeys building. The second building is 2 storeys building with higher elevation than first building. The third building is 2 storeys building with higher elevation than the second building. The fourth building is 1 storey building with higher elevation than third building. The fifth building is 1 storey building with the highest elevation. Moreover, this building located along the main road in Route Option B in Appendix 11 and 12.

Bali Asri and Srikandi Hotel are located in the near distance, so in this case the location will be presented as one point location in Srikandi hotel, but with building capacity that include both of them. Based on Appendix 13, Bali Asri and Srikandi hotel presented with ID V1 located in potential hazard with flow depth 3 - 4 m. Bali Asri and Srikandi hotel located in 10 masl that indicating that the second and third floor of this building can be allocated as shelter because the 1st building height is arround 3 until 4 m, so the second and third floor wouldn't be inundated. This building located 2831 m from shore, and 1900 m from Grindulu river. The visualization of these hotel shown on figure 5.4. for Graha Prima hotel and figure 5.5. for Bali Asri and Srikandi hotel.

First Building	**Second Building**	**Third Building**
		

Figure 5.4. Graha Prima Hotel (Source : Fieldwork, 2016)

Figure 5.5. Srikandi (Left) and Bali Asri (Right) (Source : Fieldwork, 2016)

2. Public Facility Validation

Nine from the 20 public facility result in Appendix 15 were selected based on building construction, building orientation and number of floors parameter from section 4.3.3. These building have the same building construction in medium category with bricks and cement mortar. Scoring table as on the Appendix 15 referred to scoring system parameter from section 4.3.3. show that the scoring total result range between 3 until 8. Therefore, the 3 highest total score was choosed as propose vertical evacuation building. The first highest score is 8, consist of STKIP PGRI Pacitan. The second highest score is 7, consist of SMK N 2 and MAN Pacitan. The last highest score is 6, consist of SMK N 1, SMA N 1 and SMK N 3 Pacitan.

Based on Appendix 13, STKIP PGRI presented with ID V3, SMKN 2 Pacitan presented with ID V4, MAN Pacitan presented with ID V5, SMK N

2 SMA N1 and SMK N3 Pacitan presented with ID V6 located in potential hazard with flow depth 3 - 4 m. These building located in 10 masl indicating that the second and third floor of this building can be allocated as shelter because the 1st building height is arround 3 until 4 m, so the second and third floor wouldn’t be inundated. STKIP PGRI located 2991 m from shore and 827 m from Grindulu river. MAN Pacitan located 2105 m from shore and 1118 m from Grindulu river. SMKN 2 Pacitan located 2140 m from shore and 833 m from Tamperan river. SMK N 1 Pacitan, SMA N 1 Pacitan, and SMK N 3 Pacitan located in the near distance, so the location will be presented as one location in SMA N 1 Pacitan, but building capacity will include three of them. These building located 1738 m from shore and 1746 m from Grindulu river. Moreover, MAN Pacitan located along the main road in Optional Route A in Appendix 11 and 12. While SMK N 1, SMA N 1, and SMK N 3 Pacitan located along the main road in Optional Route C on in Appendix 11 and 12. The vizualization of these building shown on the following figure 5.6.

STKIP PGRI

MAN Pacitan

SMK N 2 Pacitan

SMK N 1 Pacitan

SMA N 1 Pacitan

SMK N 3 Pacitan

Figure 5.6. Public Facility Propose Building (Source : Fieldwork, 2016)

3. **Propose Evacuation Building Capacity**

Tsunami Evacuation Building Capacity (TEBC) in this research was calculated by using Widyaningrum (2009) formula and the result shown on table 5.5.

TEBC = {(Capacity Score*Building Area*Amount of Floor)/1m^2}

As on table 5.5., the largest shelter that can accomodate a lot of people is for combination shelter of SMA N1, SMK N 1, and SMK N3.

Table 5.5. Propose Tsunami Shelter Building Capacity

ID	Name	Total Area m^2	Number of Floor	TEBC
V1	Srikandi Hotel	177	2	301
	Bali Asri Hotel	484	3	
V2	Graha Prima Hotel	1133	2	596
V3	STKIP PGRI	321	4	289
V4	SMK N 2 Pacitan	1235	3	741
V5	MAN Pacitan	303	2	91
V6	SMK N 1 Pacitan	813	3	1026
	SMA N 1 Pacitan	1302	2	
	SMK N 3 Pacitan	492	2	

(Source : Data Analysis, 2016)

5.4 HUMAN SPEED TEST

Human walking speed is a dynamic assessment. Different gender, ages, health and physical condition will affect the value of human walking speed. Human speed test was held in Pancer Door beach, on flat terrain. Based on table 5.6 it can be seen that there is an abnormal result where over age people are faster than young people (adult early). In this research, people were choosed randomly, in that case there is a possibility the abnormal speed result may be caused by different health and physical condition. Moreover, in this research people was tested to walking with average distance of 14 m and range between 7 until 25 m. This various distance also possible to be the reason of those abnormal result. However, this distance seem to be representative for human walking in evacuation for 20 minutes. In evacuation process, people tend to run to the safer place. In that case, this human walking speed test result can become the limitation of slowest human walking speed in evacuation as worst case scenario.

The result of human speed test then will be compared with the value of human walking speed based on the previous researcher. The result on table 5.6., presented on the figure 5.7. with B is for childhood category, C is for juvenile category, D is for adult category, E is for elderly category and F is for over age category. It can be seen that men human walking speed are higher than women.

Table 5.6. Human Speed Test Result for Flat Terrain in Pancer Door beach

Age Group	**Men**		**Women**	
	Speed (m/s)	**Average (m/s)**	**Speed (m/s)**	**Average (m/s)**
Toddler (0-5)	-	-	-	-
Childhood (5-11)	1.25 ; 0.84	1.05	0.73 ; 1.12	0.92
Juvenile-Early (12-16)	0.8 ; 0.8 ; 0.97	0.86	0.85 ; 0.85	0.85
Juvenile-End (17-25)	0.95	0.95	1.02 ; 1.02	1.02
Adult-Early (26-35)	1 ; 0.89	0.94	0.73	0.73
Adult-End (36-45)	0.75 ; 0.95 ; 1.04	0.91	0.8	0.8
Elderly-Early (46-55)	1.06 ; 1.06 ; 1	1.04	1.02 ; 0.8 ; 0.65	0.83
Elderly-End (56-65)	1.06	1.06	1.02 ; 0.84	0.93
Over Age (>65)	0.87	0.87	0.84	0.84

(Source : Fieldwork, 2016)

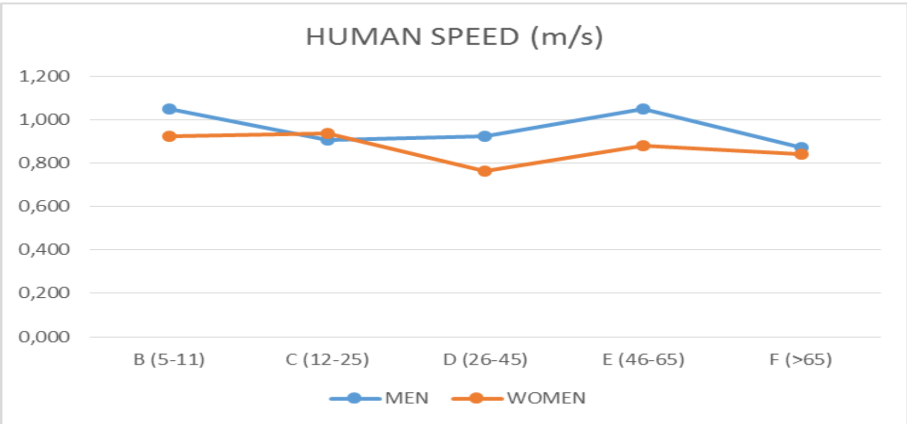


Figure 5.7. Human Speed on different age and gender
(Source : Data Analysis, 2016)

The human walking speed test result on table 5.6. was compared with the previous researcher as in Appendix 16. Appendix 16 classified age group based on previous researcher on section 2.5. and referred to Fraser et al. (2014) “Assigned Travel Speed Group Classification” in Appendix 1. The information from the Appendix 1 and 16 were analyzed into the new information on table

5.7. The same method with the information from the human speed test result on the table 5.6. was analyzed into the new information on the table 5.8.

Table 5.7. Previous Researcher Result Analysis

	Adult impaired	**Adult unimpaired**	**Child**	**Elderly**	**Running**
n	7	25	5	14	4
Min	0.58	0.88	0.56	0.21	1.79
Max	1.07	2.80	2.1	1.3	3.83
Mean	0.785	1.259	1.037	0.943	2.635

(Source : Data Analysis, 2016)

Elderly category in table 5.8. was analyzed based on over age, elderly-early, and elderly-end category from table 5.6. Adult unimpaired category in table 5.8. was analyzed based on juvenile-early, juvenile-end, adult-early, and adult-end category from table 5.6. Child category in table 5.8. was analyzed based on childhood category from table 5.6. Based on table 5.8. the minimum and maximum human walking speed test result in each category was still in the range minimum and maximum value of previous researcher on table 5.7.. Therefore, human walking speed in Pacitan on table 5.8. is within limits of human walking speed based on previous researcher on table 5.7. using classification system based on adult unimpaired, child and elderly category.

Table 5.8. Human Walking Speed Test Analysis

	Adult unimpaired	**Child**	**Elderly**
n	15	4	11
Min	0.73	0.73	0.65
Max	1.04	1.25	1.06
Mean	0.895	0.985	0.929

(Source : Data Analysis, 2016)

At the begining, this research was proposed to use human walking speed test result in different age categories to determine how much of the population in each age category that are not able to evacuate in specified time. However, based on the availability of detail data on the field that only provide number of total population without differentiated in each age category, this human walking speed test was counted in average as 0.936 m/s.

CHAPTER 6. POPULATION MODELLING

6.1 POPULATION DATA

6.1.1 Population Data in Each Neighbourhood (RW)

The aim is to calculate the number of people in each house (per building), so the number of people that need to be evacuated can be estimated. Appendix 17 show the number of people in each RW that have been collected during fieldwork. It can be seen that Sidoharjo have the highest population in 2015. Total population and number of household are conducted during fieldwork, while houses number was clarified on field work activity based on the existing building data. Sidoharjo and Kembang villages have the same average number of people in each household, consist of 4 people.

6.1.2 Population Data in Tourism Area

Population data in tourism area was collected from tourism institution, including Teleng Ria beach and Pancer Door beach. Appendix 18 show the number of tourist in Teleng Ria and Pancer Door beach in 2016 for period of January until August. The total tourist in Teleng Ria beach in 2016 was 402,705 people, the average tourist number was 50,338 people per month and 1,678 people per day. In Pancer Door beach, the total tourist in 2016 was 18,521 people, the average tourist number was 2,315 people per month and 77 people per day. This average number of tourist per day will be used for population estimation in day scenario that considering tourist.

6.1.3 Population Data in Hotel

Population data in hotel and homestay was collected by survey method in each hotel and homestay. Appendix 19 show the number of room and room capacity based on fieldwork result. This room capacity will be used for population estimation in hotel and homestay for night scenario that considering tourist.

6.2 POPULATION ESTIMATION

6.2.1 Population Estimation in The Houses

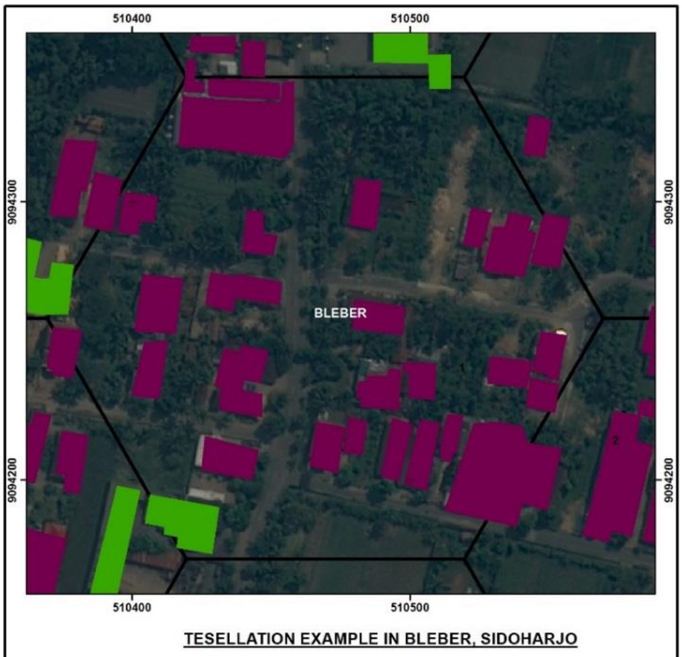
The estimation of population in the house is very important to know the number of people in each house and the distribution of the people to determine shelter that can cope all of the people in that area. Population availability data in Pacitan area from Central Bureau of Statistic is in village level. This available data is not too detail too estimate the number of people in each house. In this research, Participatoy GIS have been done in RW (neighbourhood) level to know the number of people in more detail scale and also the number of household in each RW. The number of building in each RW was counted based on information from village officer. The calculation of population estimation in house in day and night scenario referred to section 4.4.2. As in Appendix 20, average people per household was calculated by divided the total population in each RW with number of household. Number of household per house was calculated by divided number of household with number of house. In each tessellation, will consist of various number of houses, therefore in Appendix 20 as an example we used 10 houses to know the different number of people in day and night in each RW, with the limitation tessellation consist of 10 houses.

6.2.2 Population Estimation in The Public Facility

In this research, the calculation of population estimation in public facility referred to section 4.4.2 and presented on the Appendix 21. Each RW will consist of different number of public facility. Therefore, the number of population in day night scenario in each RW will different. Not all the public facility was estimated based on building area. Multi storeys school have been surveyed to know the number of people in day and night time. The number of people in hotel and homestay was estimated based on hotel room and capacity. Moreover, the number of tourist was used as consideration in tourist scenario for day time.

6.2.3 Population Estimation in Each Tessellation

In this research, there are 329 tessellations in study area. Each tessellation will consist of different number of house and different type of public facility. As an example on the figure 6.1. the tessellation calculation in day and night time without considering tourist in Bleber Sidoharjo. It can be seen that the calculated of pople in houses refered to avg person/hh and Nr of hh/house information in Appendix 20. while public facility refer to Appendix 21.



Category	Avg person/hh	Nr of hh/house	Nr of house	Day	Night
House	4,1	1	22	45	90
Shop				4	1
TOTAL POPULATION				49	91

Figure 6.1 Tessellation Example in Bleber, Sidoharjo (Source : Data Analysis, 2016)

6.3 POPULATION WITHOUT CONSIDERING TOURIST

Figure 6.2 and figure 6.3 show the difference of population in day and night time without considering tourist. It can be seen that from the legend information, maximum range population in day increasing almost 5 times from night time. It increase from range 201 – 400 in night time until range 1601-1704 in day time. This condition can be happenned because Pacitan sub-district is the governmental area in Pacitan. In Sidoharjo and Ploso there are a lot of school and institution that will consist of a lot of people that come from whether from the same villages or from other region in day time. In night time scenario, the number of population only consist of people that stay and live in those area.

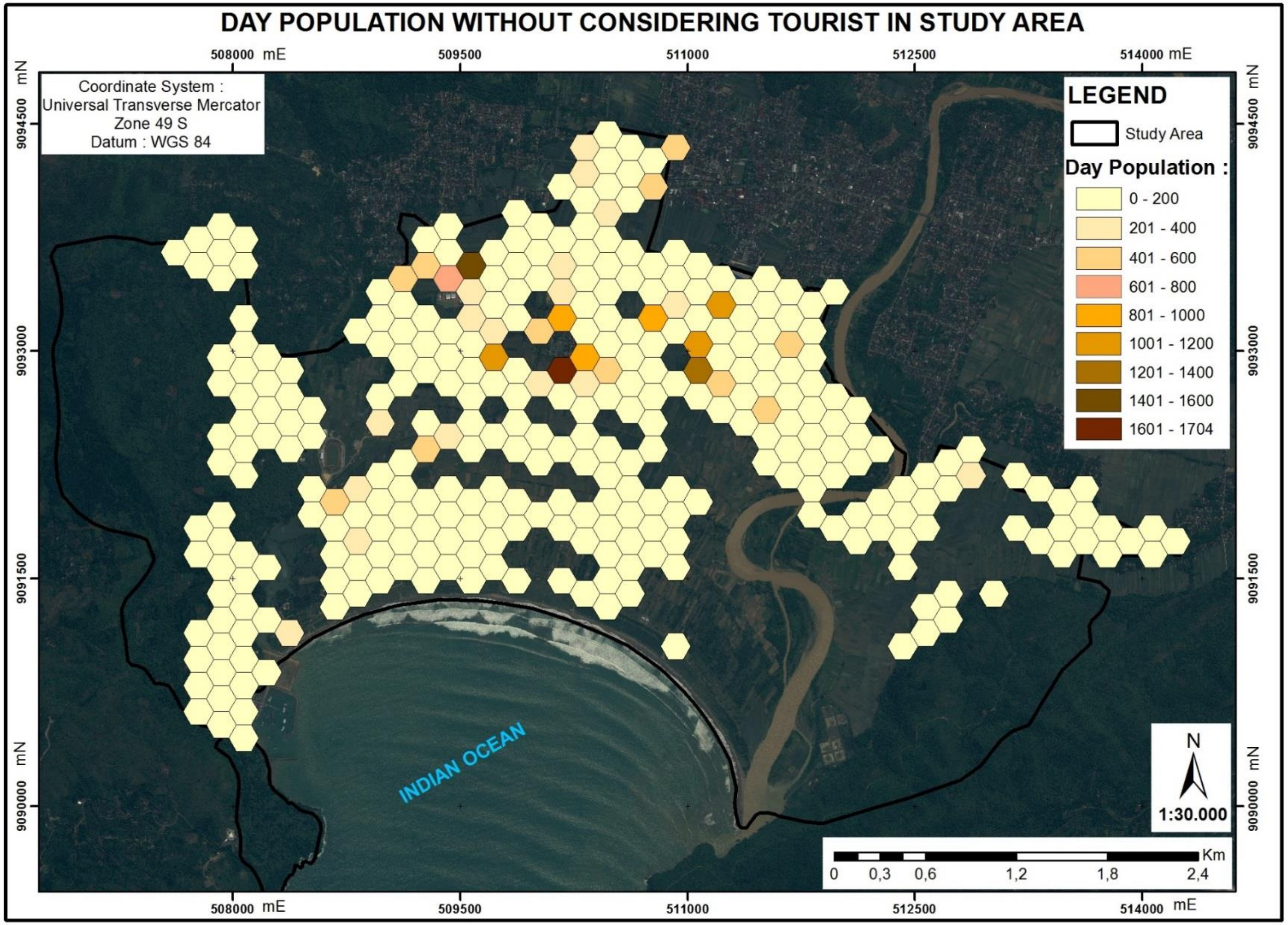


Figure 6.2. Population Distribution in Day Time Without Considering Tourist

(Source : Data Analysis, 2016)

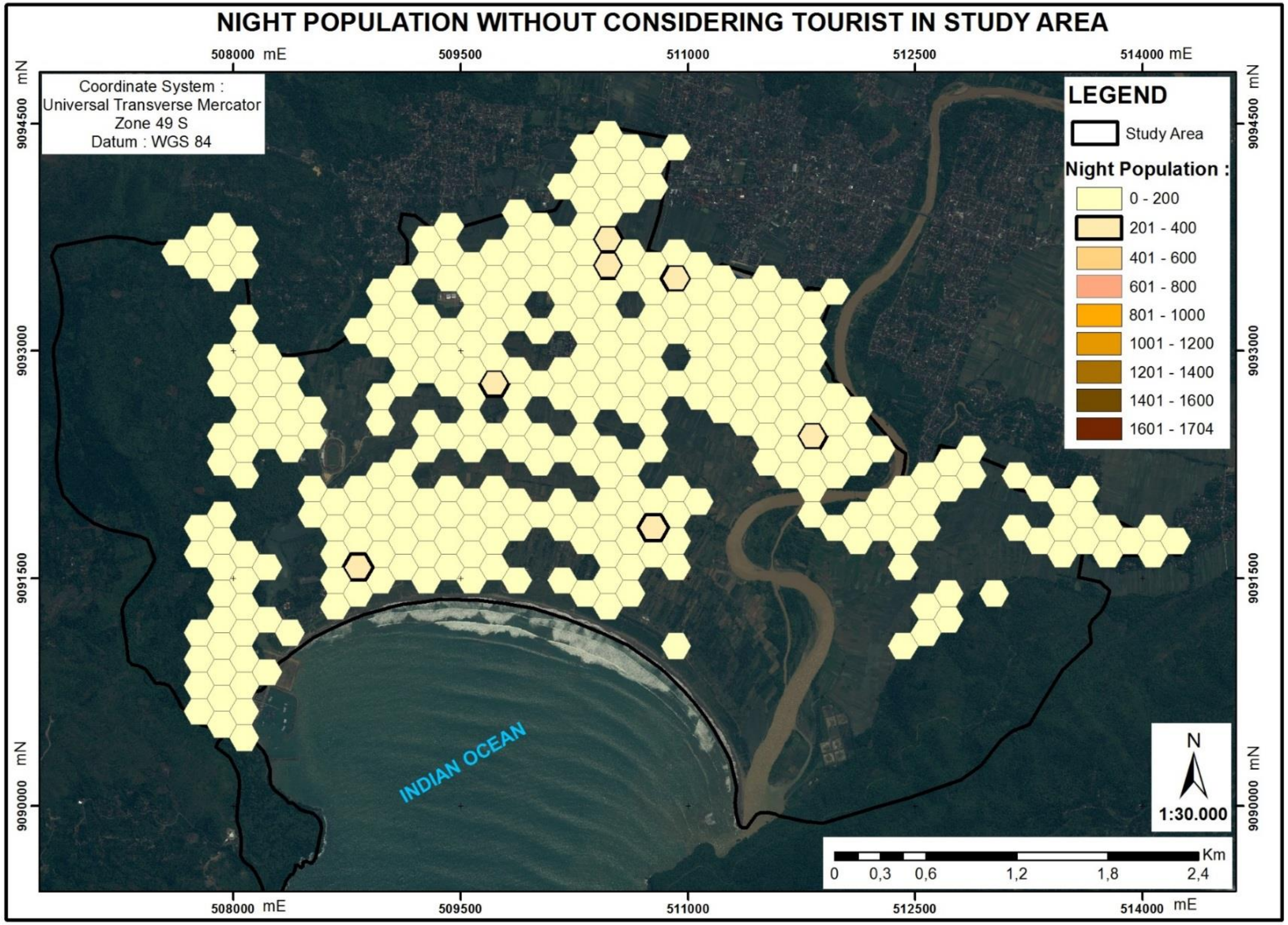


Figure 6.3. Population Distribution in Night Time Without Considering Tourist

(Source : Data Analysis, 2016)

Based on Appendix 17, the total origin population in Sidoharjo, Ploso, and Kembang villages in 2015 is 18,631 people. In this scenario without considering tourist, in day time the total population in tessellation is 31,093 as present on the figure 6.4. This condition happen because at day time there are a lot of people from outside area come to go to school and office to work.

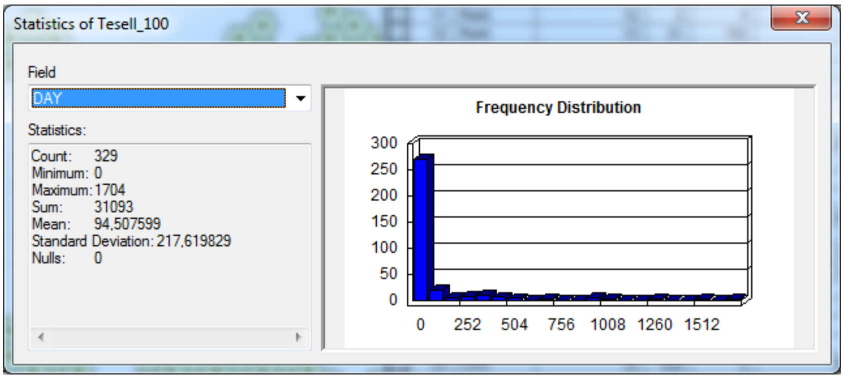


Figure 6.4. Statistic Data for Day Time in Scenario Without Tourist

In night time, the total population in tessellation is 18,769 as present on the figure 6.5. This condition happen because at night time the number of population only consist of people that live in those area and other people that stay overnight in public facility as security.

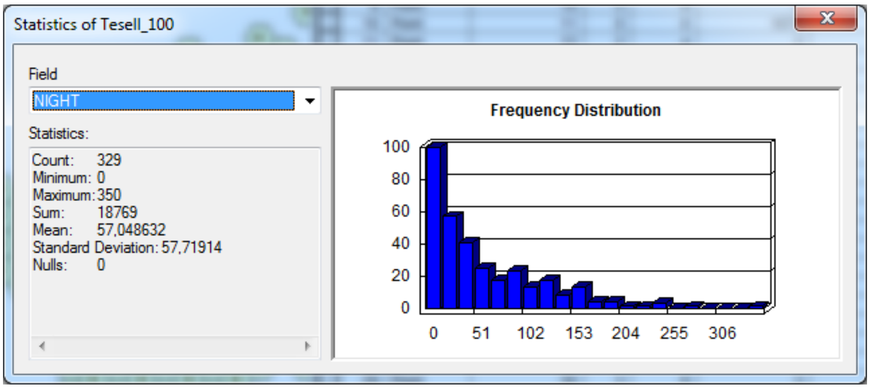


Figure 6.5. Statistic Data for Night Time in Scenario Without Tourist

6.4 POPULATION WITH CONSIDERING TOURIST

Figure 6.6 and figure 6.7 show the difference of population in day and night time with considering tourist. It can be seen that from the legend information, maximum range population in day increasing almost 5 times from night time.

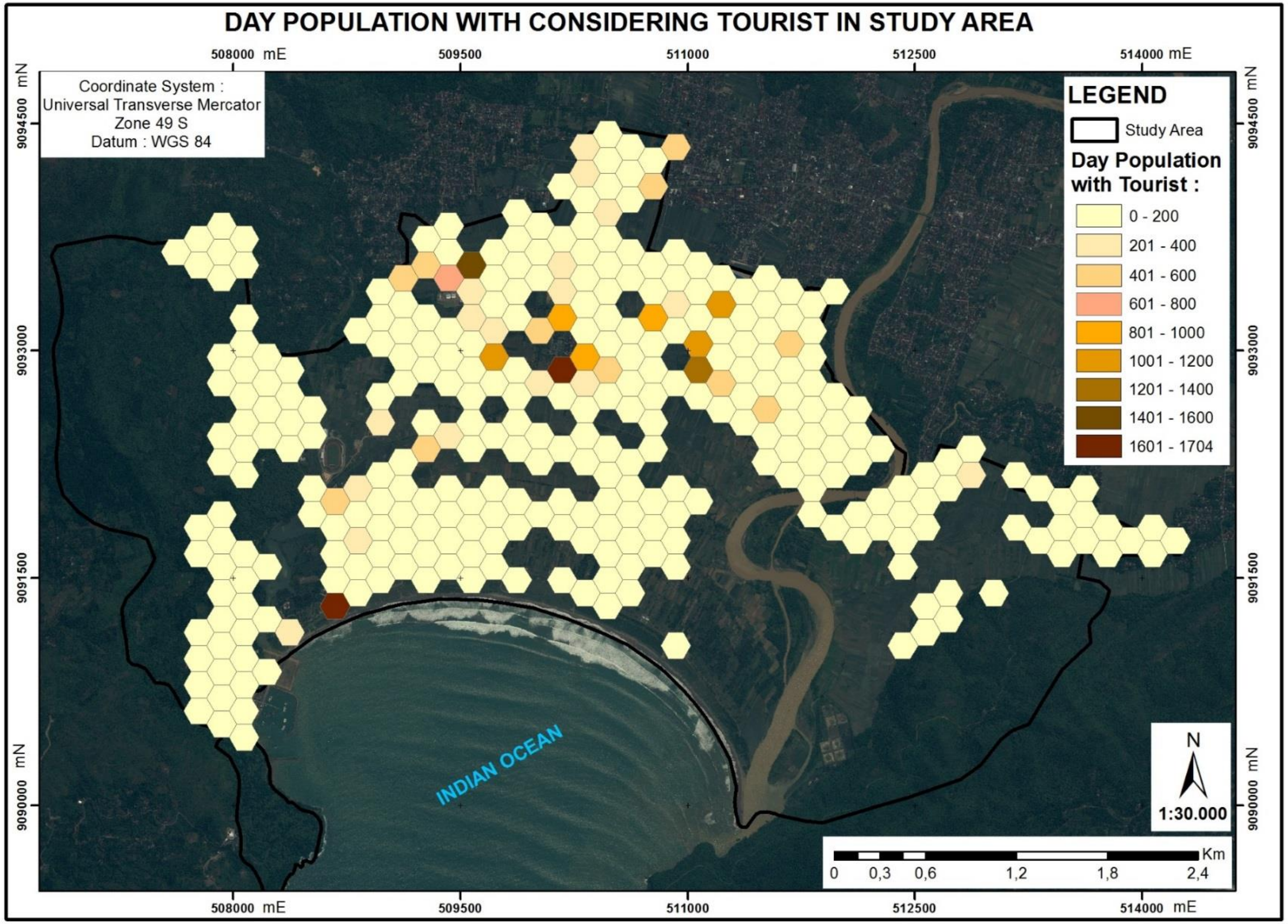


Figure 6.6. Population Distribution in Day Time With Considering Tourist
(Source : Data Analysis, 2016)

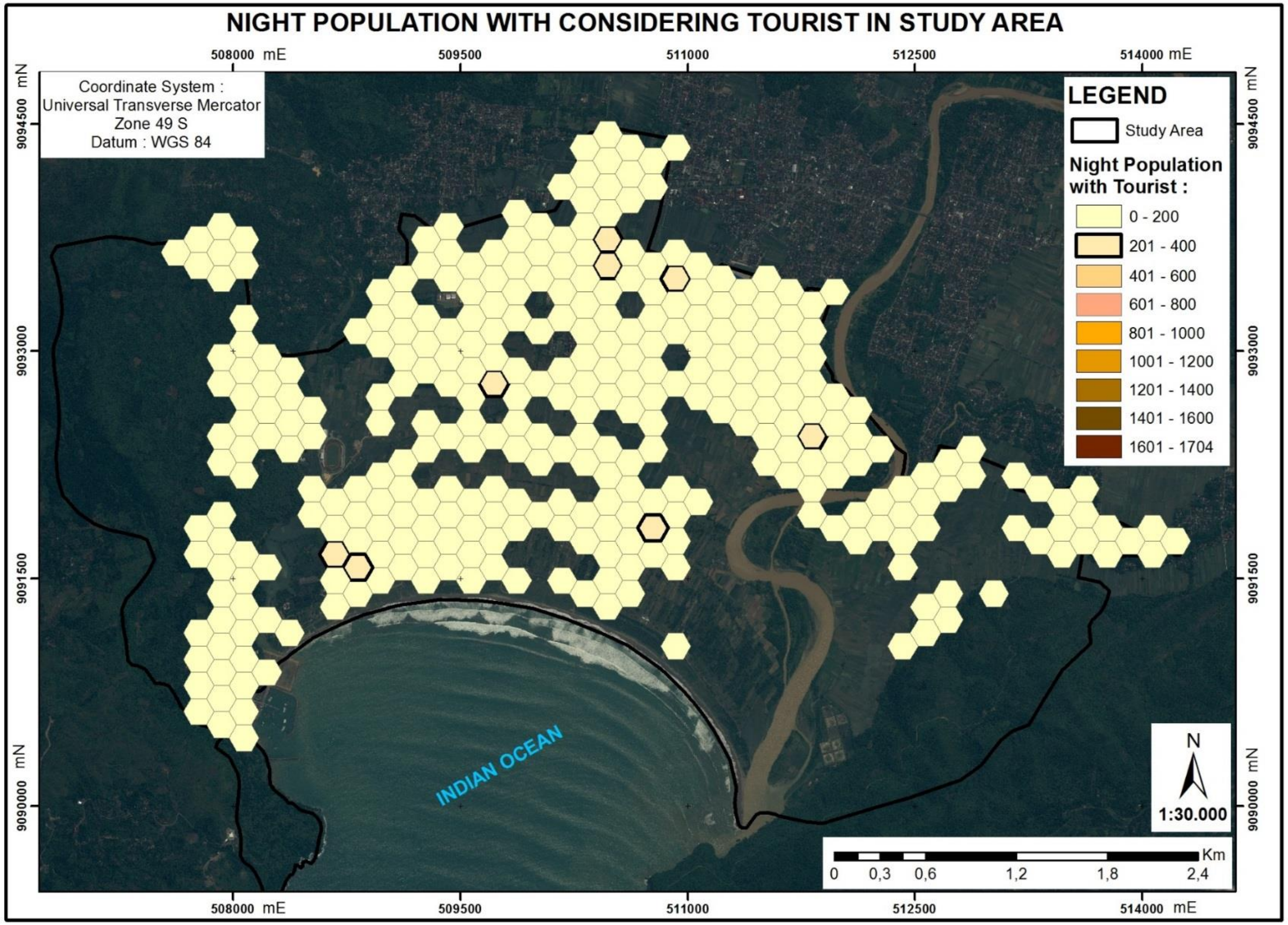


Figure 6.7 Population Distribution in Night Time With Considering Tourist
(Source : Data Analysis, 2016)

Based on Appendix 17, the total origin population in Sidoharjo, Ploso, and Kembang villages in 2015 is 18,631 people. In this scenario with considering tourist, in day time the total population in tessellation is 32,848 as present on the figure 6.8. This condition happen because at day time there are a lot of people from outside area come to go to school, to go to, and to go to tourism area like Teleng Ria with number of average tourist in 2016 is 1678 per day.

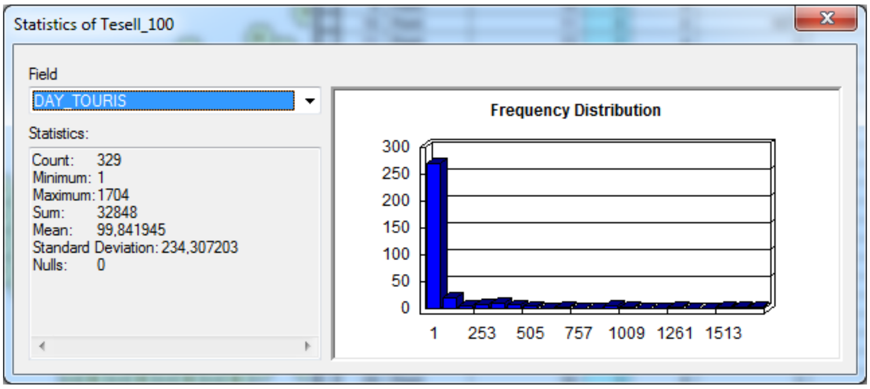


Figure 6.8. Statistic Data for Day Time in Scenario With Tourist

In this scenario with considering tourist, in night time the total population in tessellation is 19,510 as present on the figure 6.9. This condition happen because at night time the number of population only consist of people that live in those area, other people that stay overnight in public facility as security, and tourist that stay overnight in the hotel.

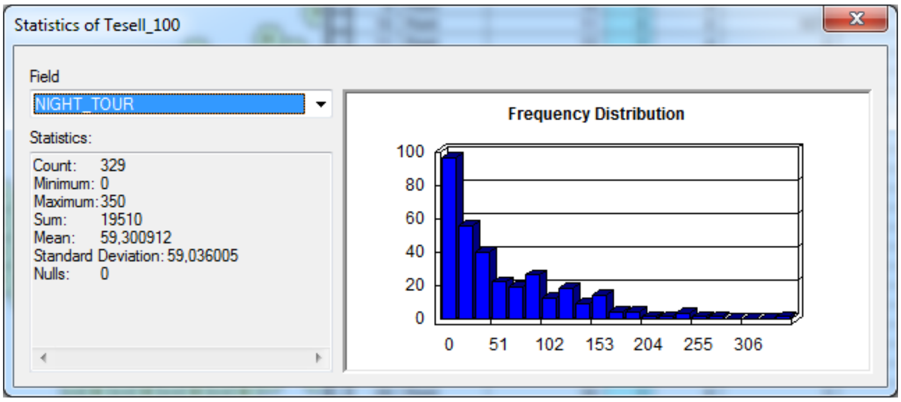


Figure 6.9. Statistic Data for Night Time in Scenario With Tourist

CHAPTER 7. EVACUATION MODELLING

7.1 ACCESSIBILITY MODELLING

By using CWD concept, accessibility modelling produce information about evacuation basin with time values information based on landuse, slope, average human speed, and shelter location (ADPC, 2007;Muck, 2008). Accessibility modelling was computed by combining new speed value of each landuse and slope with an average human speed. The new values represent how much the average speed will be conserved on the different land use types and slope values.

Table 7.1. Landuse Inverse Speed

Landuse	Value (%)	Speed (m/sec) = 0.936 * new value	Inverse Speed (sec/m)
River Channel/Pond	1	0.009	111.11
Lakes and Wetlands	2	0.019	52.63
Fishing Pools	3	0.028	35.71
Building	5	0.047	21.28
High Grass/Rice Field	40	0.374	2.674
Dense Vegetation	50	0.468	2.137
Rubber Trees	55	0.515	1.942
Open Vegetation	60	0.562	1.779
Coconut Tree	65	0.608	1.645
Beach	70	0.655	1.527
Open Field	80	0.749	1.335
Roads	100	0.936	1.068

(Source : Data Analysis, 2016)

Based on calculation result on the table 7.1. the high landuse values of inverse speed (river channel/pond, lakes and wetlands, fishing pools) are not passable but for this calculation need to be considered to provide a complete surface for the study area. The smallest landuse values of inverse speed is road with 1.068 sec/m that indicating the needed of short time in walking every meter. Based on table 7.2. it can be seen that the higher slope percentage, the higher number of inverse speed that indicating the needed of long time in walking every meter.

Table 7.2. Slope Inverse Speed

Slope (%)	Value (%)	Speed (m/sec) = 0.936 * new value	Inverse Speed (sec/m)
0 - 3	100	0.936	1.068
3 - 6	85	0.796	1.256
6 - 9	70	0.655	1.527
9 - 12	55	0.515	1.942
12 - 15	45	0.421	2.375
15 - 18	40	0.374	2.674
18 - 21	35	0.328	3.049
21 - 24	30	0.281	3.559
24 - 27	25	0.234	4.274
27 - 30	20	0.187	5.348
30 - 33	15	0.028	35.714
33 - 36	14	0.026	38.46
36 - 39	13	0.024	41.67
39 - 42	12	0.022	45.45
42 - 45	11	0.021	47.62
>45	10	0.019	100

(Source : Data Analysis, 2016)

Inverse evacuation speed was calculated by combination of landuse and slope inverse speed and average human walking speed. Inversing the speed (m/sec becomes sec/m) by multiplying each cost (landuse, slope, and human speed). The inverse evacuation speed result then was processed with the shelter location to create final result of evacuation shelter accessibility from every cell size of the study area to the shelter location on figure 7.1. Each shelter generate catchment area that include the information about time needed to access shelter. From figure 7.1, in study area, consist of 5 horizontal location and 6 propose shelter building.

As can be seen in figure 7.1., there are some zone that is not realistic for evacuation. It can be happened because in defining time basin (catchment area) the surface value of each cell represent the cost (time) to go from any source point to go to the closest evacuation location using the fastest route. This map identifies which cells will be allocated to which evacuation location. Those, the distribution of evacuation location will affect the catchment area. Moreover, the defining of catchment area could intersect by natural barriers, buildings, rivers, lakes, sandy areas, or very high slope. In CWD method, there is a setting to put constant value 1 for masking that useful to find the highest evacuation time values inside cells belonging, for example, to river channel land use type. This value was useful to have a more realistic idea of the highest evacuation time for this study area.

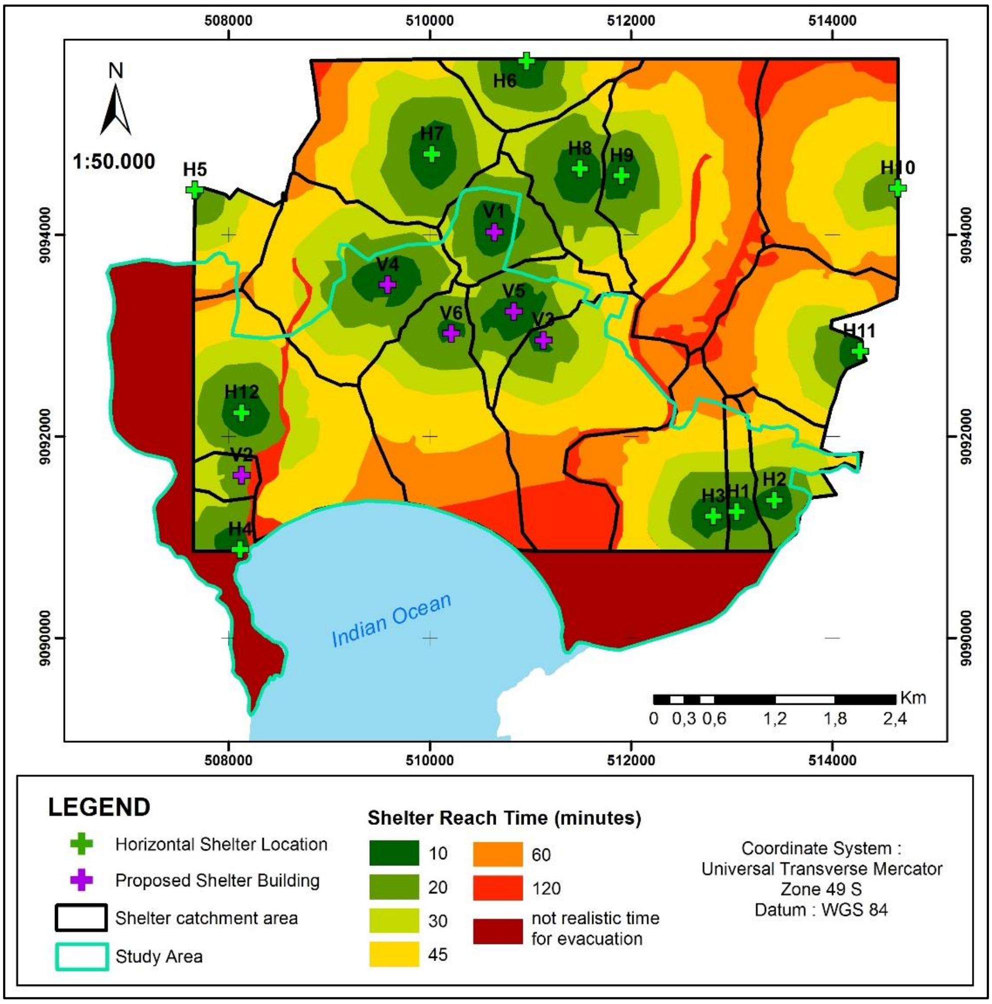


Figure 7.1. Evacuation Shelter Accessibility (Source : Data Analysis, 2016)

As in Appendix 23, the not realistic zone in the west part of study area was consist of slope with new slope value of 30 that indicating topography with 21

– 24 % and inverse speed 3.559 sec/m based on table 7.2. This high value of inverse speed was identified as not realistic for evacuation time by this program. The same explanation was applied for the not realistic zone in the east side of study area that consist of slope with new slope value of 30. Moreover, this area consist of river that have inverse speed value of 111.11 sec/m based on table 7.1. This high value of inverse speed was identified as not relistic for evacuation time by this program.

7.2 ABILITY MODELLING

Evacuation shelter ability to accomodate population in study area, presented in figure 7.2. Each shelter have their own capability to provide accomodation for people, and each tessellation consist of population number in different scenario. The result of shelter capacity, and the number evacuees in different scenario is presented in Appendix 23. The result in Appendix 23 was conducted based on calculation the total of population from tessellation that located in the range of evacuation time 10 minute, 20 minute, 30 minute, 45 minute, 60 minute and 120 minute in different scenario.

In figure 7.2, it can be seen that from the limitation time of 20 minutes time to evacuate from Pacitan government, in walking condition there are still a lot of tessellation that are indicating a lot of people that are not be able to be sheltered and/or not be able to go to shelter location because of insufficient time. However, based on illustration of the reaction scheme and time sequences of an early warning system from section 2.3, there are warning decision, warning disemination, warning receipt and warning reaction stage that should be passed before evacuation stage. This explanation indicating that if people response due to evacuation warning is slow, there will be a possibility number of victim that bigger than number of people that can not be sheltered based on calculation shown in figure 7.2. and in Appendix 23. In that case to reduce the number of victim, this research propose recommendation in each catchment area including :

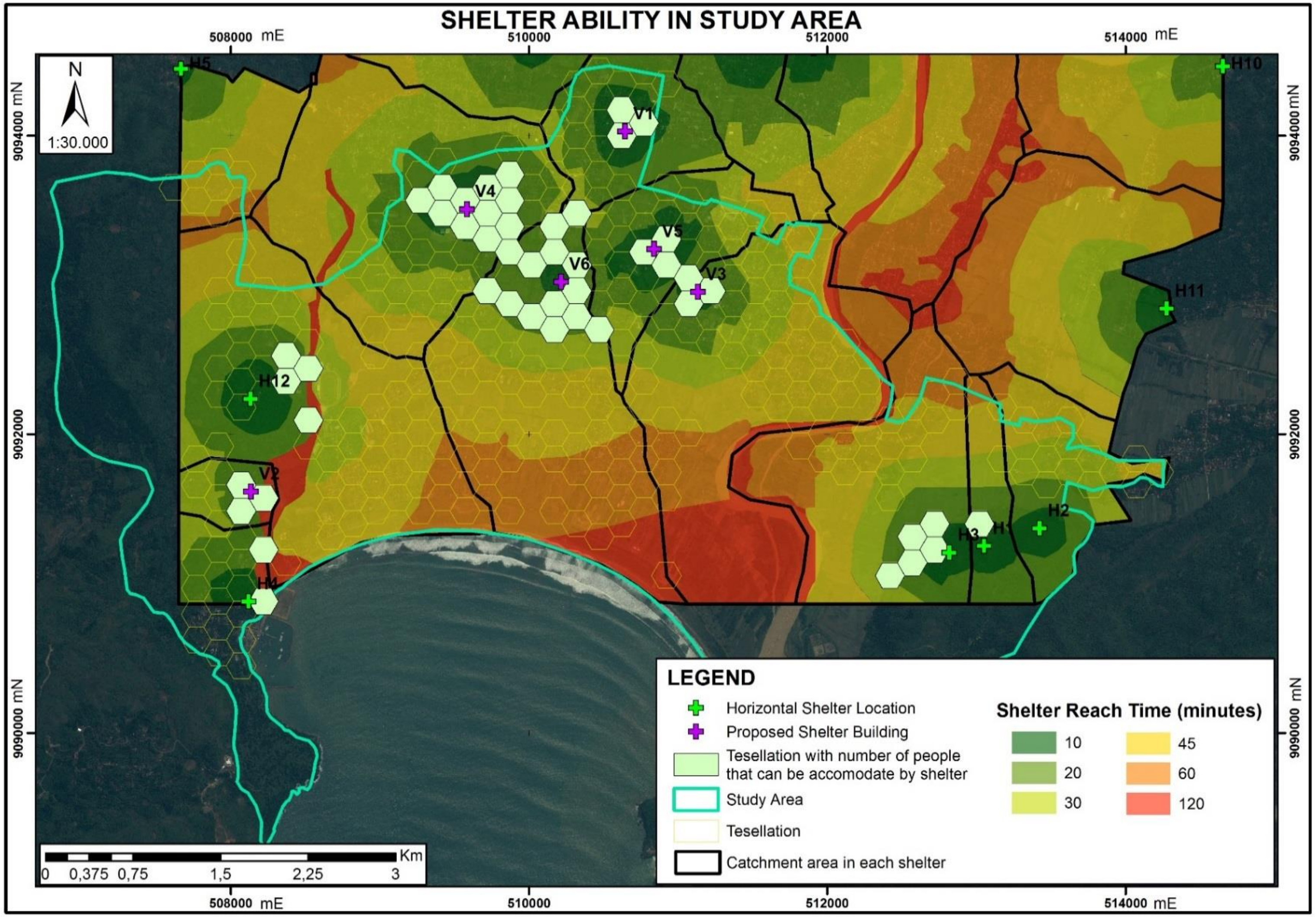


Figure 7.2. Evacuation Shelter Ability (Source : Data Analysis, 2016)

1. Shelter H1 “Puncak Kepangrono”

Based on Appendix 23. , Shelter H1 “Puncak Kepangrono” can receive people at least 647 people, because this shelter is open field area and located in hilly area, so it still possible for people to safe their life in the location that higher than this place and can accomodate more than 647 people. Based on Appendix 22. and figure 7.3, in this shelter, only 7 people in day (with and without tourist) and also 14 people in night (with and without tourist) that can access this shelter in limitation time 10 minutes in walking condition. However, there are still 15 people in day (with and without tourist) and also 28 people in night (with and without tourist) that possible to reach this shelter in time arround 20 until 45 minutes in walking condition.

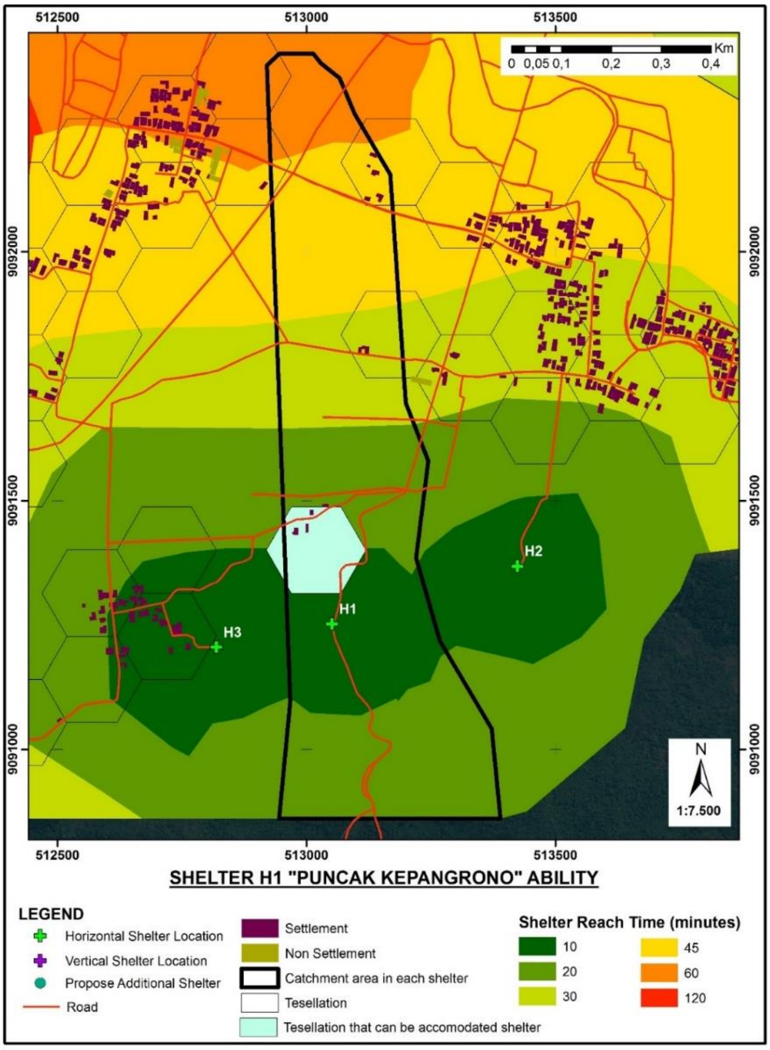


Figure 7.3. Shelter H1 “Puncak Kepangrono” Ability

Overall, in limitation time of 20 minutes, this shelter can accomodate 31.8% people in day (with and without tourist) and 32.5% people in night (with and without tourist) scenario. To solve this problem, the rest of population in this shelter catchment can access shelter by using own vehicle, because this area only consist of local people, so there is low possibility to create traffic in this area. Moreover, this shelter also still can accomodate people from nearest catchment area like shelter H2 and shelter H3.

2. **Shelter H2 "Puncak Watugupit"**

Based on Appendix 23. , Shelter H2 "Puncak Watugupit" can receive people about 120 people. Based on Appendix 23. and Appendix 25, in this shelter, there are nobody that can access this shelter in limitation time 20 minutes in walking condition. However, there are still 504 people in day (with and without tourist) and also 971 people in night (with and without tourist) that possible to reach this shelter in time arround 20 until 45 minutes in walking condition.

Overall, in limitation time of 20 minutes, this shelter can accomodate 0% people in day and night (with and without tourist) scenario because there are nobody that live in this area with limitation 20 minutes walking. To solve this problem, the rest of population in this shelter catchment can access Shelter H1 by using own vehicle, because this area only consist of local people, so there is low possibility to create traffic in this area. The reason why choosing shelter H1, because this shelter only can be accessed by walking based on the road condition that consist of stairs.

3. **Shelter H3 "Puncak Ngelowo Indah"**

Based on Appendix 23. , Shelter H3 "Puncak Ngelowo Indah" can receive people about 120 people. Based on Appendix 23. and Appendix 26, in this shelter, only 49 people in day (with and without tourist) and also 99 people in night (with and without tourist) that can access this shelter in limitation time 20 minutes in walking condition. However, there are still 793 people in day (with and without tourist) and also 759 people in night (with and without tourist) that possible to reach this shelter in time arround 20 until 60 minutes in walking condition.

Figure 7.4. Masjid Sirnoboyo (Source : Fieldwork, 2016)

Overall, in limitation time of 20 minutes, this shelter can accomodate 5.8% people in day (with and without tourist) and 11.5% people in night (with and without tourist) scenario. To solve this problem, the rest of population in this shelter catchment can access Shelter H1 by using own vehicle, because this area only consist of local people, so there is low possibility to create traffic in this area. The reason why choosing shelter H1 is because in this shelter only can be accessed by walking based on the road condition that consist of stairs. Another option that people can do is by going to the additional propose shelter location as mosque called “Masjid Sirnoboyo” that present as A1 in Appendix 24 and figure 7.4. Mosque area is 194 m^2, with 2 floors, and capacity for 151 people. This mosque located outside study area, 2496 m from shoreline, 315 m from Grindulu river , but 88 m from Jelok river with elevation about 15 masl.

4. **Shelter H4 “Puncak Tamperan”**

Based on Appendix 23. , Shelter H4 “Puncak Tamperan” can receive people about 168 people. Based on Appendix 23. and Appendix 27, in this shelter, there are 152 people in day (with and without tourist) and 289 people in night (with and without tourist) in limitation time 20 minutes. However, based on topography condition in this shelter, there are only 9 people in day (with and without tourist) and 10 people in night (with and without tourist) that stay at the lower elevation that need to be evacuated in limitation time 20 minutes. Overall, in limitation time of 20 minutes, this shelter can accomodate 100% people in day and night (with and without tourist) scenario.

There are also still 166 people in day (with and without tourist), and 329 people in night (with and without tourist) that located in undefined area. Undefined area is an area that near this shelter H4, still inside study area, but not in the shelter area. This area have topography condition that higher than shelter location. In that case, there are no need to allocate people in this area.

5. **Shelter H12 "Puncak KandangSapi"**

Based on Appendix 23. , Shelter H12 "Puncak Kandangsapi" can receive people at least 7174 people because this shelter is open field area and located in hilly area, so it still possible for people to safe their life in the location that higher than this place and can accomodate more than 7174 people. Based on Appendix 23. and Appendix 28, in this shelter, there are 226 people in day (with and without tourist) and 448 people in night (with and without tourist) in limitation time 20 minutes. However, based on topography condition in this shelter, there are only 62 people in day (with and without tourist) and 119 people in night (with and without tourist) that stay at the lower elevation that need to be evacuated in limitation time 20 minutes.

In time range 20 until 45 minutes, there are 2861 people in day (without tourist), 4539 people in day (with tourist), 1810 people in night (without tourist), 2023 people in night (with tourist). However, based on topography condition in this shelter, there are only 2720 people in day (with and without tourist) and 1529 people in night (with and without tourist) that stay at the lower elevation that need to be evacuated in limitation time 20 until 45 minutes. There are also still 436 people in day, 240 people in night without considering tourist and 246 people in night with considering tourist that need to be evacuated in time between 45 until 60 minutes in walking condition.

Overall, in limitation time of 20 minutes, this shelter can accomodate 1.9% people in day (with and without tourist) and 6.3% people in night (with and without tourist) scenario. To solve this problem, the rest of population in this shelter catchment can access this shelter by mass vehicle that can take a lot of people because this catchment also consist of tourist. Another option that people can do in this shelter is by going to the additional propose shelter location including Hotel Rajawali (A2 in Appendix 24), MIN Sidoharjo (A3 in Appendix 24) and SMK Bina Karya (A4 in Appendix 24) as shown on the figure 7.5. Hotel Rajawali area is 374 m^2, with 2 floors, and capacity for 98 people. This hotel located 403 m from shoreline, 290 m from Tamperan river with elevation about 10 masl. MIN Sidoharjo area is 319 m^2, with 2 floors, and capacity for 96 people. This school located 844 m from shoreline, 170 m from Tamperan river with elevation about 10 masl. SMK Bina Karya area is 1945 m^2, with 2 floors, and capacity for 584 people. This school located 980 m from shoreline, 210 m from Tamperan river with elevation about 10 masl. However, this additional building got the lowest total score as in Appendix 14 and 15.

Figure 7.5. Hotel Rajawali (left), MIN Sidoharjo (Middle) and SMK Bina Karya (Right) (Source : Fieldwork, 2016)

There are also still 153 people in day (with and without tourist), 51 people in night (without tourist) and 171 people in night (with tourist) that located in undefined area. Undefined area is an area that near this shelter H12, still inside study area, but not in the shelter area. This area have topography that higher than shelter location. In that case, there are no need to allocate these people.

6. **Shelter V1 "Hotel Bali Asri, Srikandi"**

Based on Appendix 23., Shelter V1 "Hotel Bali Asri and Srikandi" can receive people about 301 people. Based on Appendix 23. and Appendix 29, in this shelter, there are 1150 people in day (without tourist), 1180 people in day (with tourist), 687 people in night (without tourist) and 897 people in night (with tourist) in limitation time 10 minutes. However, due to limitation of this building capacity, the shelter ability in Appendix 28 present the tessellation that can be accomodated. Those tessellation consist of 247 people in night without tourist and 365 people in night with tourist. In day scenario, those shelter consist of 607 people, therefore this area need additional shelter. However, there are still 1862 people in day (with and without tourist), 932 people in night (with and without tourist) that need to be evacuated in time 10 until 30 minutes in walking condition.

Overall, in limitation time of 10 minutes, this shelter can accomodate 10% people in day (with and without tourist) and 15.3% people in night (without tourist) and 20% people in night (with tourist) scenario. To solve this problem, the rest of population in this shelter catchment can access shelter by using by mass vehicle that can take a lot of people because this catchment consist of tourist. Another option is by going to the additional propose shelter location in Hospital (A6 in Appendix 24) that is outside study area as in figure 7.6. Hospital area is 1467 m^2, with 4 floors, and capacity for 3080 people. This hospital located 3165 m from shoreline, 1405 m from Grindulu river with elevation about 15 masl.

Figure 7.6. Hospital
(Source : Fieldwork, 2016)

7. **Shelter V2 "Hotel Graha Prima"**

Based on Appendix 23. , Shelter V2 "Hotel Graha Prima" can receive people about 596 people. Based on Appendix 23. and Appendix 30, in this shelter, there are 50 people in day (without tourist), 86 people in night (without tourist) and 197 people in night (with tourist) in limitation time 20 minutes. However, based on topography condition in this area, only 22 people in day (with and without tourist), 29 people in night (without tourist) and 140 people in night (with tourist) live in the area that lower than shelter and need to be evacuated.

There are also still 64 people in day (with and without tourist) and 128 people in night (with and without tourist) that do not need to be evacuated,because located in the higher place. Overall, in limitation time of 20 minutes, this shelter can accomodate 100% people in day & night (with and without tourist).

8. **Shelter V3 "STKIP PGRI Pacitan "**

Based on Appendix 23. , Shelter V3 "STKIP PGRI Pacitan" as school building can receive people about 289. Based on Appendix 23 and Appendix 31, there are 3193 people in day (without tourist), and 854 people in night (with and without tourist) in limitation time 20 minutes. However, due to limitation this building capacity, the shelter ability in Appendix 31 present the tessellation that can be accomodated. Those tessellation consist of 193 people in night with and without tourist. In day scenario, those shelter consist of 2472 people, therefore this area need additional shelter. However, there are still 2618 people in day (with and without tourist), 3490 people in night (without tourist) and 3510 people in night (with tourist) that need to be evacuated in time 20 until 120 minutes in walking condition.

Overall, in limitation time of 20 minutes, this shelter can accomodate 4.9% people in day (with and without tourist) and 4.4% people in night (with and without tourist). This catchment area, including school and tourism area (hotel) that will consist a lot of people in day and night scenario. Based on this reason, this catchment area need to be built shelter building because there are no option for additional shelter from exting multi storeys public facility in this area.

9. Shelter V4 "SMK N 2 Pacitan"

Based on Appendix 23. , Shelter V4 "SMK N 2 Pacitan" as school building can receive people about 741 people. Based on Appendix 23. and Appendix 32, there are 5205 people in day (without tourist), and 1266 people in night (with and without tourist) in limitation time 20 minutes. However, due to limitation this building capacity, the shelter ability in Appendix 32 present the tessellation that can be accomodated. Those tessellation consist of 701 people in night with and without tourist. In day scenario, those shelter consist of 3382 people, therefore this area need additional shelter. However, there are still 422 people in day (with and without tourist), 3490 people in night (without tourist) and 823 people in night (with and without tourist) that need to be evacuated in time 20 until 45 minutes in walking condition.

Overall, in limitation time of 20 minutes, this shelter can accomodate 13.9% people in day (with and without tourist) and 12.8 % people in night (with and without tourist). To solve this problem, the rest of population in this shelter catchment can access another shelter (Puncak Sedeng Shelter as H5 in figure 7.2) by using own vehicle, because this area only consist of local people, so there is low possibility to create traffic in this area. Another option is by going to the additional propose shelter location called SMP N 3 Pacitan (A5 in

Appendix 24) as in figure7.7. This school area is 681 m^2, with 2 floors, and capacity for 204 people. This school located 1933 m from shoreline, 1706 m from Grindulu river with elevation about 10 masl.

Figure 7.7. SMP N 3 Pacitan (Source : Fieldwork, 2016)

10. Shelter V5 "MAN Pacitan"

Based on Appendix 23. , Shelter V5 "MAN Pacitan" as school building can receive people about 91 people. Based on Appendix 23. and Appendix 33, there are 3275 people in day (without tourist), and 1544 people in night (with and without tourist) in limitation time 20 minutes. However, due to limitation this building capacity, the shelter ability in Appendix 32 present the tessellation that can be accomodated. Those tessellation consist of 54 people with and without tourist. In day scenario, those shelter consist of 202 people, therefore this area need additional shelter. However, there are still 242 people in day (with and without tourist), 478 people in night (with and without tourist) that need to be evacuated in time 20 until 30 minutes in walking condition.

Overall, in limitation time of 20 minutes, this shelter can accomodate 2.6% people in day (with and without tourist) and 2.6% people in night (with and without tourist).This catchment area, including school that will consist a lot of people in day and night scenario. Based on this reason, this catchment area need to be built shelter building because there are no option for additional shelter from exting multi storeys public facility in this area.

11. Shelter V6 "SMA N 1, SMK N 1, SMK N3"

Based on Appendix 23., Shelter V6 "SMA N1, SMK N1, SMK N3 Pacitan" as school building can receive people about 1026 people. Based on Appendix 23. and Appendix 34 there are 6070 people in day (without tourist), and 900 people in night (without tourist) and 916 people in night (with tourist) in limitation time 20 minutes. However, due to limitation this building capacity, the shelter ability in Appendix 34 present the tessellation that can be accomodated. Those tessellation consist of 900 people with and without tourist. In day scenario, those shelter consist of 6070 people, therefore this area need additional shelter. However, there are still 1581 people in day (without tourist), 1658 people in day (with tourist), 2533 people in night (without tourist) and 2533 people in night (with) that need to be evacuated in time 20 until 120 minutes in walking condition.

Overall, in limitation time of 20 minutes, this shelter can accomodate 13.4% people in day (without tourist), 13.3% people in day (with tourist) 26.2% people in night (without tourist) and 25.3% people in night (with tourist).This catchment area, including school and tourism area that will consist a lot of people in day and night scenario. Based on this reason, this catchment area need to be built shelter building because there are no option for additional shelter from exting public facility in this area.

The following explanation divided shelter ability category in accomodate people for 20 minutes evacuation time based on the previous shelter explanation.

1. **Shelter that can accomodate all of the population**

   This category consist of shelter H4 " Puncak Tamperan" and shelter V2 "Hotel Graha Prima" that can accomodate 100% people in each catchment.
2. **Shelter that can not accomodate all of the population**

   This category consist of shelter H2 "Puncak Watugupit" that can not accomodate people because there are nobody that live in those area of 20 minutes evacuation time.
3. **Shelter that possible to acomodate people from other shelter**

   This category consist of shelter H1 "Puncak Kepangrono" that still have more space to accomodate people especially from near shelter in H2 and H3.
4. **Shelter that need additional propose shelter building**

   This category consist of :

   - Shelter H3 "Puncak Ngelowo Indah" that only can accomodate 5.8% people in day and 11.5% people in night (for with and without tourist scenario).

- Shelter H12 “Puncak KandangSapi” that only can accomodate 1.9% people in day and 6.3% people in night (for with and without tourist scenario).
- Shelter V4 “SMK N 2 Pacitan” that only can accomodate 13.9% people in day and 12.8 % people in night (for with and without tourist scenario).
- Shelter V1 “Hotel Bali Asri, Srikandi” that only can accomodate 10% people in day (with and without tourist) and 15.3% people in night (without tourist) and 20% people in night (with tourist) scenario.

5. **Shelter that need to build a new shelter building**

   This category consist of :

- Shelter V3 “STKIP PGRI Pacitan” that only can accomodate 4.9% people in day and 4.4% people in night (for with and without tourist scenario)
- Shelter V5 “MAN Pacitan” that only can accomodate 2.6% people in day and night (for with and without tourist scenario).
- Shelter V6 “SMA N 1, SMK N 1, SMK N 3” that only can accomodate 13.4% people in day (without tourist), 13.3% people in day (with tourist) 26.2% people in night (without tourist) and 25.3% people in night (with tourist).

In defining shelter, this research using criteria from Mardiatno (2008a) and Budiarjo (2006) that seems to be applicable with the limitation of tsunami hazard map that only considering flow depth. The criteria including building distance that at least 200 m from shore and river, building orientation that should be parallel with wave direction, number of floor that should be at least 2 and building construction that should be with with bricks and cement mortar. However, in case to build a new shelter, vertical building criteria need to be developed like using an earthquake-proof building strength criteria factor from SNI 03-1726-2002 for Indonesian Earthquake Building Resistant Standard. Moreover, building should be able to withstand the hydraulic forces of the incoming waves, and withstand also severe damages created by floating debris and huge objects carried forward with the incoming waves or brought back during the backwash. In addition, building height should be sufficiently above the maximum water height. (S. J. Scheer et al., 2012).

8.1 COMPARISON ROUTE MODELLING

Network Analysis is used for evacuation route modelling to find out the most effective route to evacuate communities to a safer place. There are five types of network analysis layers (ESRI, 2008 on Dewi, 2010). Two of them are compared in the following explanation to find the suitable route.

a) Finding the best route, to find efficient route from one location to another location. The idea is to create relation route between one point with another. The example of this method result can be seen on the following figure 8.1. The green line is the best route that is defined from the green point location that is set manually in each tessellation. The blue point is present the last point that put on the map. In that case, the route connected the first point location to the very last point location. Related to defining evacuation route, this method is not applicable, because evacuation route should connected every place arround shelter location to the shelter location, not only connected the begining to the end point location.

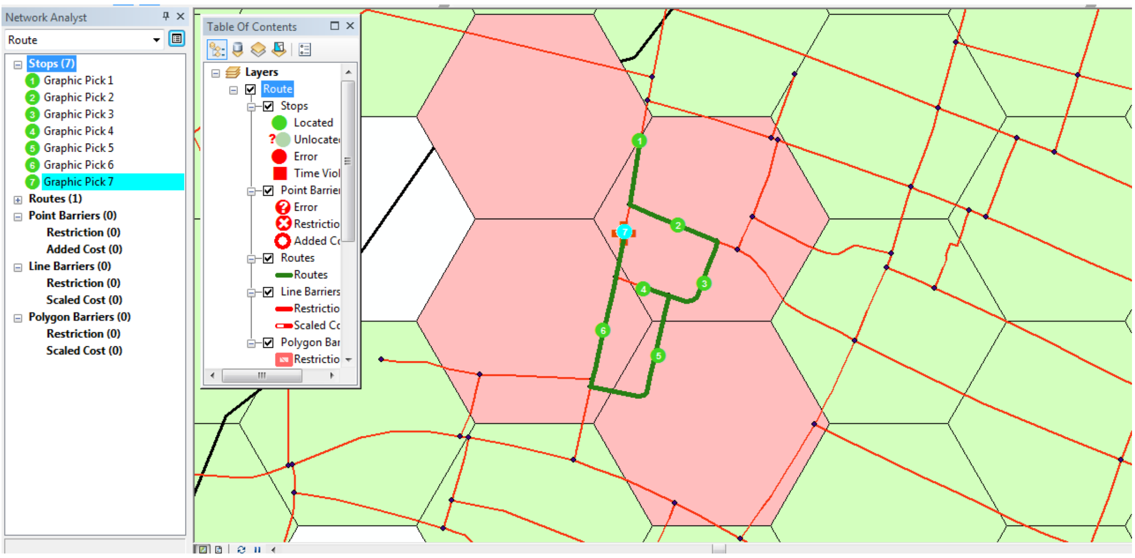


Figure 8.1. Finding The Best Route in ArcGIS

b) Finding the closest facility, for determining which facility is closest, also give the best route to the facility. This method is suitable for defining evacuation route, because it considering time impedance based on calculation result from the table 4.9. and following table 8.1. Actual speed (Vs) on table 8.1.. was calculated based on Vs result on table 4.9. Vs was changed into minutes by multiply with 60, because we want to know the time needed to move from one location to another location in minute based on route result. Width_length on table 8.1 then divided to multiply result to create FT_MINUTES and TF_MINUTES number (FT refers to From To and TF refers to To From, it is based on the direction of traffic flow). After processing on ArcGIS using finding the closest facility, we can define which road that can accomodate people based on time needed for evacuate.

Table 8.1. Road Attribute Table on ArcGIS

OB	Shape	Width	Width_Leng	Vs	FT_MINUTES	TF_MINUTES	ONEWAY	ROAD_NAME
22	Polyline	7	624,189974	0,8	8,946723	8,946723	B	Jl. Mayjend Sutoyo
23	Polyline	7	1219,260362	0,8	17,476065	17,476065	B	Jl. Mayjend Sutoyo
23	Polyline	7	3346,368251	0,8	47,964612	47,964612	B	Jl. Mayjend Sutoyo
23	Polyline	7	5198,030814	0,8	74,505108	74,505108	B	Jl. Mayjend Sutoyo
87	Polyline	7	5198,030814	0,8	74,505108	74,505108	B	Jl. Mayjend Sutoyo
74	Polyline	11	440,823844	0,8	6,465416	6,465416	B	Jl. Letjend Suprapto
74	Polyline	11	223,095235	0,8	3,272063	3,272063	B	Jl. Letjend Suprapto
74	Polyline	11	14259,87	0,8	209,14476	209,14476	B	Jl. Letjend Suprapto
12	Polyline	7	532,975194	0,8	7,639311	7,639311	B	Jl. Letjend S. Parman
13	Polyline	7	366,704585	0,8	5,256099	5,256099	B	Jl. Letjend S. Parman

The example of this method result can be seen on the figure 8.2. The green line is the closest route that is defined from the green point incident location to the green point facility location. In this method, the point was classificed into two , the incident point and the facility point. Therefore, the route was defined by connected each incident point location to the facility point location. Related to defining evacuation route, this method is applicable, because evacuation route should connected every place arround shelter location to the shelter location. Moreover, this method give the information about time needed to move from one location to another location based on time impedance calculation. It can be seen on the figure 8.2. that the time needed to go to facility location from each incident location is arround 8 until 16 minutes.

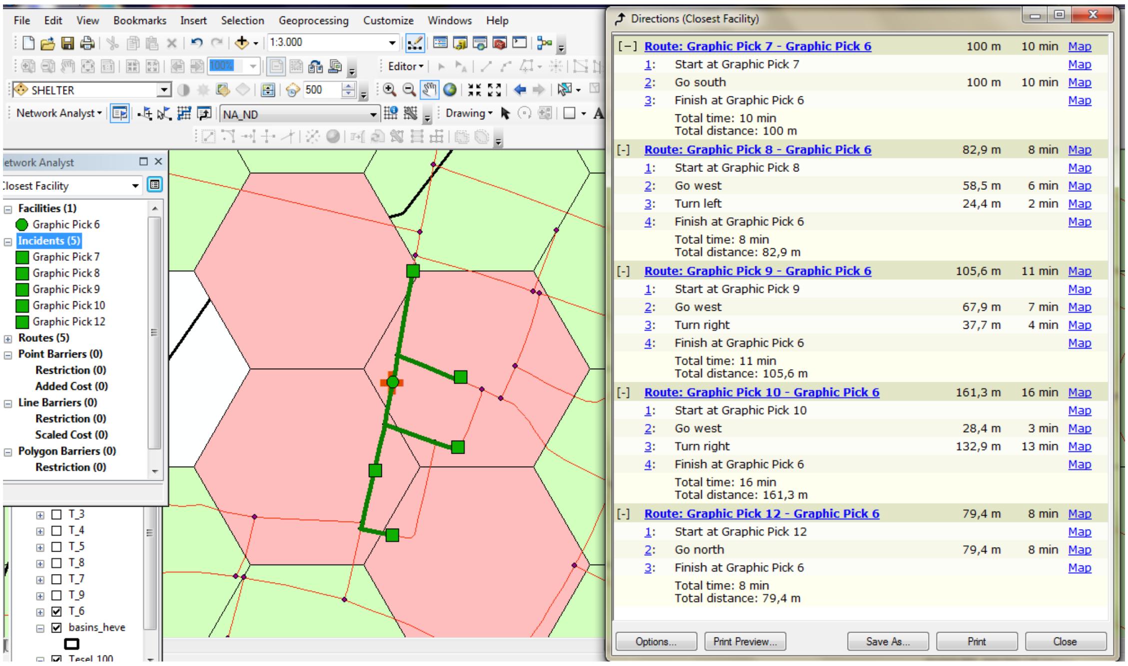


Figure 8.2. Finding The Closest Facility in ArcGIS

8.2 FINDING THE CLOSEST FACILITY

Based on network analysis method comparison, it seems like finding the closest facility is the best method that need to be applied in this research. Finding route was conducted in each of catchment area , so the route in this research consist of route from centralized population that can evacuate in less than 20 minutes of time to the nearest shelter, by considering time impedance using finding the closest facility on Network Analysis. As an example, the route result in catchment V3 and V5 shown on the figure 8.3. while for the whole study area present on the figure 8.4. It can be seen that the route follow the existing road network to connected tessellation location to shelter location. The route was symbolized with arrow line that show the direction. People that located in the tessellation area with blue color should follow the route direction to the shelter location. Pacitan sub district is only small city, so the population density and road network is not so big. Therefore, in this case the effectiveness using this method is not really dominant. This method is suitable to be applied in the city with big density of road network, therefore, the route can define the shorter distance related to shorter time to go from one location to another location.

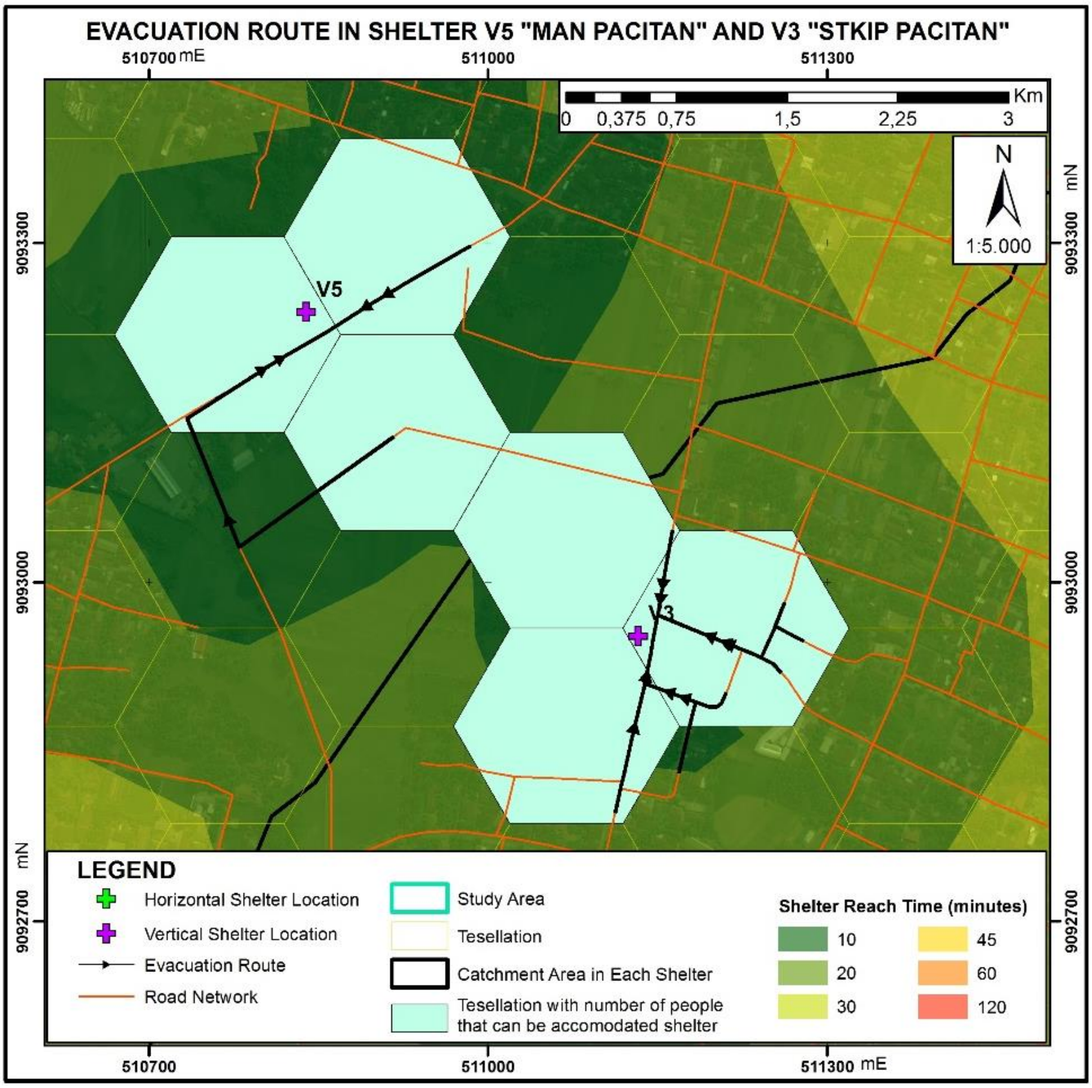


Figure 8.3. Evacuation Route in Shelter V3 an V5

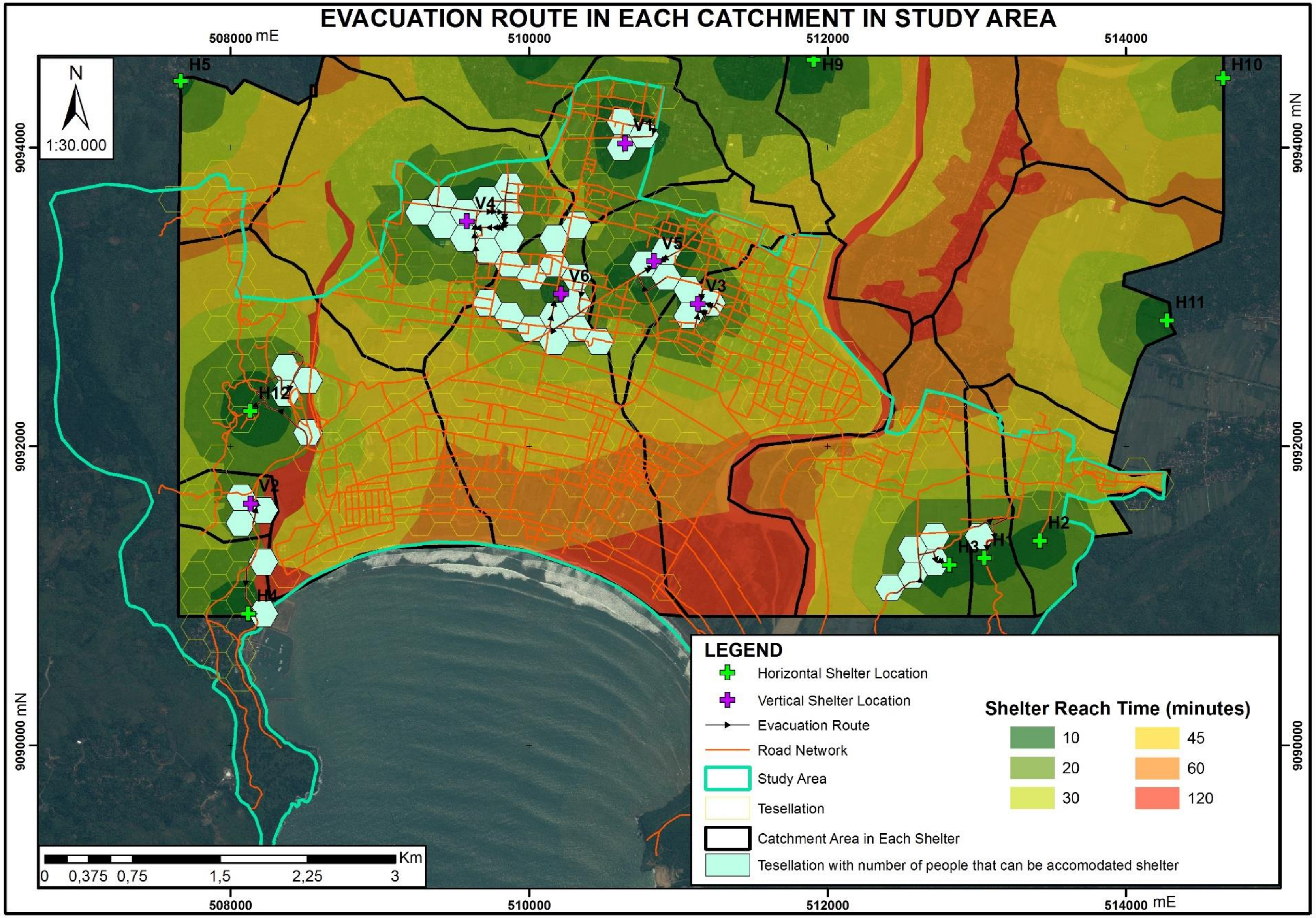


Figure 8.4. Evacuation Route in Study Area (Source : Data Analysis, 2016)

CHAPTER 9. DISCUSSION,CONCLUSION, AND RECOMMENDATION

9.1.DISCUSSION

In this part, the general discussion and limitation of this research will be explained. Pacitan has never experienced a tsunami in the past (Latief et al, 2000 in Mardiatno, 2008a). Due to the limitation of tsunami hazard modelling result, tsunami hazard potential was referred to tsunami flow depth. Moreover, the study area only focus in 3 villages (Sidoharjo, Ploso, Kembang), not for the whole tsunami inundation area because of the limitation of time.

Vertical evacuation building in this research was proposed based on criteria from Budiarjo (2006) and Mardiatno (2008a). Building construction should be at least with bricks partly and/or whole, cement mortar, no reinforcement. Building orientation should be parallel with wave direction. Building should located at least 200 m from shore and river. Building should at least have 2 floors. These category seems appropriate to be applied with the existing tsunami potential hazard based on flow depth. However, for detail tsunami hazard that considering velocity for example , building criteria need to be developed by using criteria like earthquake building strength.

In this research, population estimation in different scenario only based on the building use. Population estimation based on landuse seems to be more detail because the distribution of people that working not in the building also considered. However, the detail data about people working distribution in neighbourhood (RW) is not available. Moreover, based on the limitation time on the field, population estimation on the public facility only considering building area, except for multi storey school building that conducted based on field work activity. For population scenario that considering tourist, this research use assumption from average number of tourits in 2016.

In developing evacuation modelling, previous researcher using existing human walking speed result from other country. However in this research, human speed was tested in tourism area. This test referred to different age category from from

Indonesian Health Department (2009) with average distance of 14 m and range between 7 until 25 m. The development of human walking speed test for local people are also needed for comparison result. Due to limitation time, this research only focus on human walking speed test for tourist.

Cost weighted distance (CWD) method was used to define shelter accessibility and ability in each shelter location based on landuse, slope and average human walking speed. The distribution of shelter location will affect the catchment area result. Therefore, this method can be considered as evaluation from the existing horizontal shelter location. Evaluation in this case means to see whether the location of shelter appropriate or not to accomodate the population in that location.

Finding the closest facility was choosed in defining route based on the comparison result with finding the best route method. In finding the closest facility, the route was generated from each incident point location to facility (shelter) location. Moreover, this method also give information about which route that need short time to go to shelter location.

9.2.CONCLUSION

The main objective of this research is to determine the most suitable tsunami evacuation building location and the optimal evacuation routes based on population dynamic in day and night time and considering tourism and human behavior in disaster evacuation. The following describe the conclusion:

1. **Vertical Shelter Criteria**

   Based on literature study and the existing tsunami hazard map, the most suitable tsunami vertical evacuation building criteria in this research :

   - Building construction at least 2 floors with bricks and cement mortar.
   - Building orientation should be parallel with wave direction.
   - Building location should be more than 200 m from shoreline and river. Mardiatno (2008a) and Budiarjo (2006)

2. **Tourist Perspective**

   Based on tourist interview result, tourist perspective related to human behaviour in disaster evacuation in Pacitan including :

- Homing Behavior, for people that think the way to going back to home when they were asked to evacuate.
- Proximal Characteristic, for people that think to run to the nearest higher ground or building when they were asked to evacuate.
- Straight Characteristic, for people that do not have any idea where to go when they were asked to evacuate, and just want to follow crowd.

Moreover, tourist intensity in visiting tourism area will change their perspective related to disaster evacuation and potential hazard in that area.

3. Tsunami Horizontal Location

In Pacitan, tsunami horizontal location as temporary shelter was set in the elevated area, outside tsunami potential hazard with open field area landuse.

4. Population Dynamic

Population dynamic in Pacitan was estimated based on the estimation of people in houses and public facility in day and night scenario. For scenario that considering tourist in day scenario was estimated based on the average number of tourist in Pacitan beach. In night scenario was estimated based on the possibility of people that stay in hotel and homestay. Based on the result, shelter catchment V3 (STKIP PGRI Pacitan), V5 (MAN Pacitan) and V6 (SMA N 1, SMK N1 and SMK N 3 Pacitan) are the area that consist a lot of people whether in the day or night scenario. The reason is because in those shelter catchment, consist of school, office, and tourism area that will consist a lot of people that come from other area in day and night scenario.

5. Shelter Accessibility and Ability

In determining shelter accessibility and ability, the combination of CWD and Network Analysis was applied in Pacitan. CWD was used to create service area (catchment area) by considering landuse, slope, average human speed and shelter location as input data. Hexagonal tessellation was used to concentrate the population. Each shelter area will create catchment area based on landuse, slope and average human speed. Each catchment area will consist a lot of tessellation that have information about population in day and night (with and without tourist) scenario. Not all the population in tessellation be able to reach shelter. 3 from 11 propose shelter in this research (V3, V5, V6) need to build additional shelter because there are no option to propose additional shelter from existing multi storeys public facility.

6. **Evacuation Route**

Network Analysis by using finding the closest facility layer in ArcGIS was used to create evacuation route in each catchment area. The route connected the center of population in each tessellation that able to reach shelter in given time to the shelter location based on time impedance calculation.The route follow the existing road network to connected tessellation to shelter location.

The following table 9.1. addresses the research questions of this research.

Table 9.1. Reference of research question achievement

No	Research Question	Reference
1	**Finding the most suitable tsunami vertical evacuation building criteria based on literature study.**	
	a. What are the criteria for vertical evacuation buildings based on literature study?	Sub Chapter 2.4.
	b. What are the most suitable criteria for vertical evacuation buildings to be applied in Pacitan study area?	Sub Chapter 2.4.
2	**Analyzing tourist perspective related to human behaviour in disaster evacuation to determine the potential tsunami evacuation building location.**	
	a. What is tourist perspective related to human behaviour in disaster evacuation based on interview result	Section 5.3.2.
	b. What is the existing multi function building type and location that is suitable for tsunami vertical evacuation?	Section 5.3.3.
	c. How is the existing vertical building capacity to accommodate people?	Section 5.3.3.
3	**Analyzing the existing tsunami horizontal evacuation locations.**	
	a. Where is the location of existing tsunami horizontal evacuation?	Section 5.3.1.
	b. How is the condition and capacity of the location to accommodate people?	Section 5.3.1.
4	**Analyzing the population dynamic in day and night time, with considering with and without tourist scenarios based on population data and field work.**	
	a. How is the population distribution based on building use condition in day and night scenario without tourist*?	Sub Chapter 6.3.
	b. How is the population distribution based on building use condition in day and night scenarios with tourist*?	Sub Chapter 6.4.

5	**Analyzing tsunami shelter accessibility and ability for population based on land use and slope condition and shelter capacity.**	
	a. How can slope aspect affect the human speed of evacuation?	Sub Chapter 7.1
	b. How is population ability to evacuate based on estimation tsunami arrival time and tsunami existing evacuation building capacity in day, night, with and without tourist scenarios?	Section 2.7.4 Sub Chapter 7.2
	c. In case of inadequate building shelter, how many additional vertical building are needed based on population numbers in the different scenarios?	Sub Chapter 7.2.
6	**Determining an optimal tsunami evacuation routes**	
	What is the most suitable evacuation route modelling to be applied in Pacitan study area?	Section 2.7.5 Sub Chapter 8.2

9.2. RECOMMENDATION

1. The development of scenario using tsunami hazard map that considering detail information like tsunami velocity is needed for the next research.
2. The comparison of human speed test between tourist and local people is necessary to be applied, to create 2 scenario in defining catchment area by considering human speed result from local people and tourist.
3. Related to population estimation in different scenario, it need to be developed by using approach by people that working in different landuse in each RW to define population distribution in day and night time.
4. The method combination in this research can be used to improve existing evacuation plan in Pacitan, with considering population dynamic in day and night scenario and also with and without considering tourist scenario.
5. The propose shelter and additional shelter location can become recomendation for government to improve the existing evacuation shelter.

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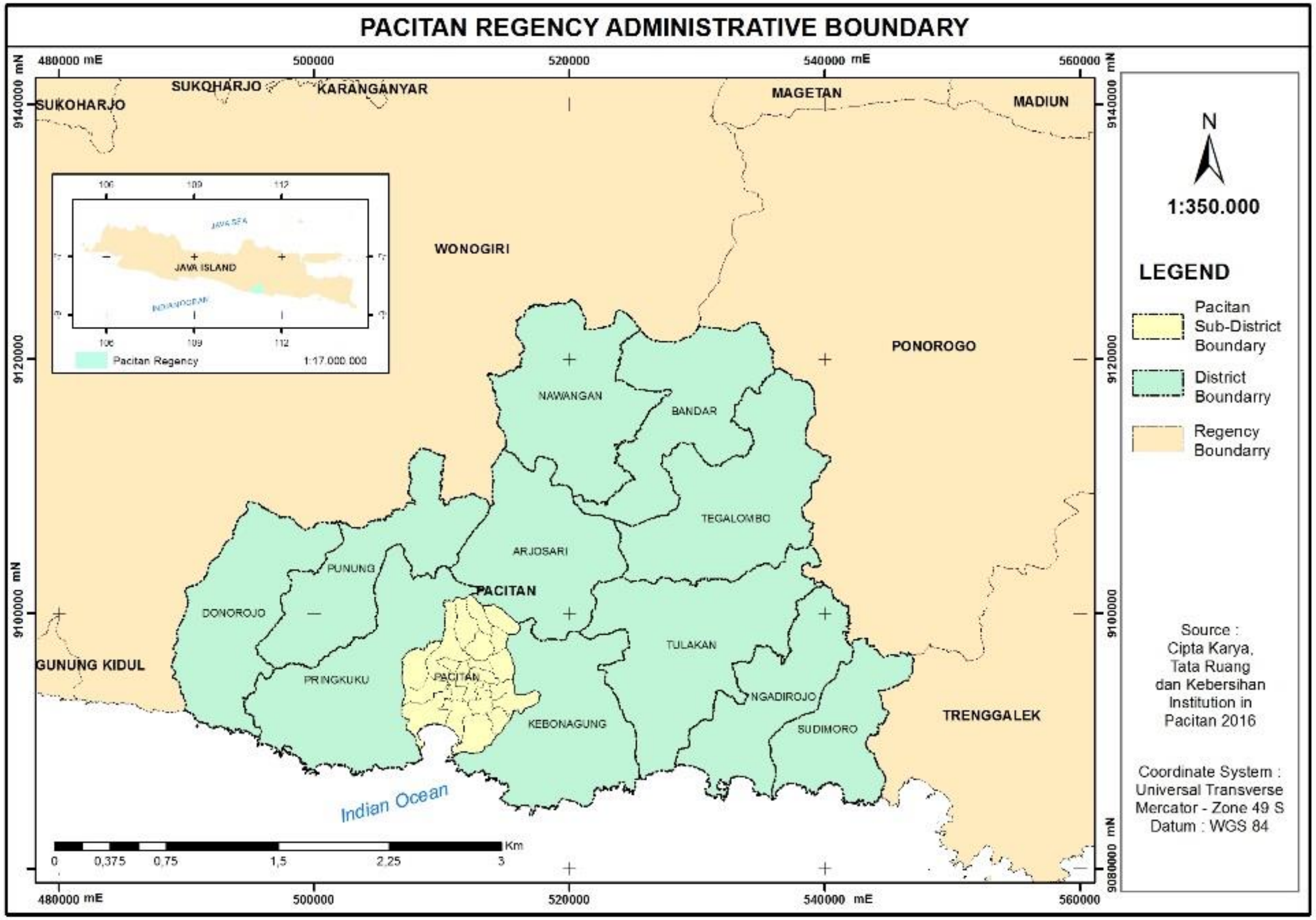
APPENDICES

Appendix 1. Table of Pedestrian Travel Speeds Used in Previous Evacuation Analysis

Source	Original Description	Assigned Travel Speed Group	Travel Speed (m/s)
FEMA (2008)	Mobility impaired Non mobility impaired	Adult impaired Adult unimpaired	0.89 1.79
Wood and Schmidtlein (2012)	Running-fast, moderate, slow Walking-fast, moderate, slow Walking-US crosswalk standards	Running Adult unimpaired Adult unimpaired	3.83 ; 2.68 ; 1.79 1.52 ; 1.22 ; 0.91 1.10
Cabinet Office Government of Japan (2005)	Walking: old man alone Walking: crowd, "sighted" Walking: people with disability Walking up stairs: old man	Elderly Adult unimpaired Adult impaired Elderly	1.30 0.88 ; 1.29 0.91 0.21
Yagi and Hasemi(2010)	Walking (horizontal) Walking (upstairs)	Adult unimpaired Adult impaired	1.00 0.58
Chooramun et al.(2012)	Unimpaired walking speed	Adult unimpaired	1.50
Revi and Singh (2006)	Adult mean walking speed Older person mean walking speed Children mean walking speed	Adult unimpaired Elderly Child	1.39 1.11 0.56
Knoblauch et al. (1996)	Younger person (14-64) design speed, 15 th %ile Older person (65+) design speed, 15th %ile	Adult unimpaired Elderly	1.22 ; 1.25 0.91 ; 0.97
Park et al. (2012)	Age 65 + Age 13 - 64	Elderly Adult unimpaired	1.25 1.51
Liu et al. (2009)	Age 6-17 Age 18-69 Age 70 +	Child Adult unimpaired Elderly	1.20 1.40 1.00
Johnstone (2012)	All	Adult unimpaired	1.25
Liu et al. (2006)	Young walking Old walking	Adult unimpaired Elderly	1.10 0.80
Goto et al. (2012)	Normal walkers max speed Slow walkers max speed	Adult unimpaired Adult impaired	1.50 0.75
Sugimoto et al. (2003)	Person : pushing a perambulateor, with a child Walking elderly person : independent, group	Adult unimpaired Elderly	1.07 ; 1.02 0.95 ; 0.75
Post et al. (2009)	Age 15-62: male,female Age <14 Age >62	Adult unimpaired Child Elderly	2.80 ; 2.70 2.10 0.70
Mas et al. (2012)	All-maximum walking speed	Adult unimpaired	1.33

(Source : Fraser et al. 2014)

Appendix 2. Figure of Pacitan Regency Administrative Boundary



Appendix 3. Table of Determination of Priority Areas to Tsunami Danger in Pacitan City

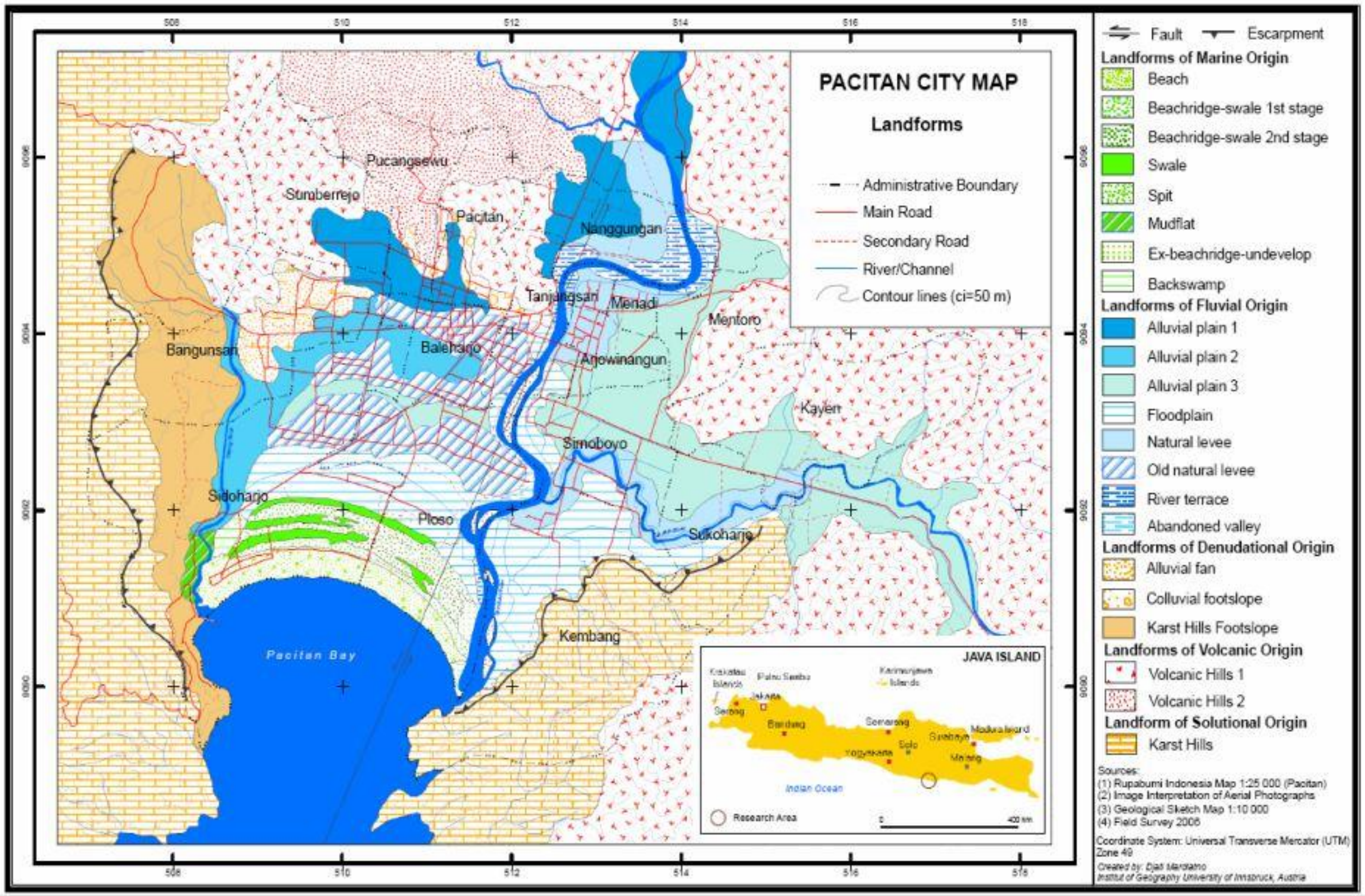
Villages	Simple				Ho=5				Ho=9				Ho=12				Mw=8.5				Total
	Ra	Rb	RL	Rp	Ra	Rb	RL	Rp	Ra	Rb	RL	Rp	Ra	Rb	RL	Rp	Ra	Rb	RL	Rp	
Arjowinangun	2	2	3	2					2	2	3	2	2	2	3	2	3	2	4	3	39
Baleharjo	2	2	3	2	4	2	4	4	3	2	3	2	4	2	4	4	5	4	5	5	**66**
Bangunsari	1	2	3	2	1	2	4	2	1	2	3	2	1	2	3	2	4	5	5	5	52
Kayen	2	2	4	2					2	2	4	2	1	2	4	4	4	2	5	4	46
Kembang	3	4	5	4	4	2	4	2	4	4	5	4	5	4	5	2	5	5	5	4	**80**
Menadi	2	2	3	2					2	2	3	2	2	2	3	2	3	4	4	4	42
Mentoro	2	2	4	3					2	2	4	3	1	2	4	4	2	4	4	4	47
Nanggungan	1	2	4	2					1	2	4	2	2	2	4	4	2	3	4	4	43
Pacitan	2	2	3	2					2	2	3	2	2	2	3	2	4	4	5	4	44
Ploso	5	3	5	5	5	2	3	5	5	3	5	5	5	3	5	5	5	5	5	5	**89**
Pucangsewu	2	2	3	1					2	2	3	1	2	2	3	1	4	1	2	1	32
Sidoharjo	5	4	5	5	5	4	4	3	5	4	5	4	5	4	5	5	5	5	5	5	**92**
Simoboyo	4	4	5	5	2	2	3	2	4	4	5	5	4	4	5	5	5	5	5	5	**83**
Sukoharjo	2	2	4	2					2	2	4	2	2	2	4	4	3	4	5	4	48
Sumberrejo	1	2	3	2					1	1	3	2	1	1	3	2	1	4	5	4	36
Tanjungsari	1	2	3	2					1	2	3	2	1	2	3	2	1	4	5	4	38

Note: 5=very high; 4=high; 3=medium; 2=low; 1=very low. Scores reflect relative comparison only. The biggest number of total means the first priority area

Ra=risk of selected mobile asset; Rb=risk of building; RL=risk of land function; Rp=risk of population

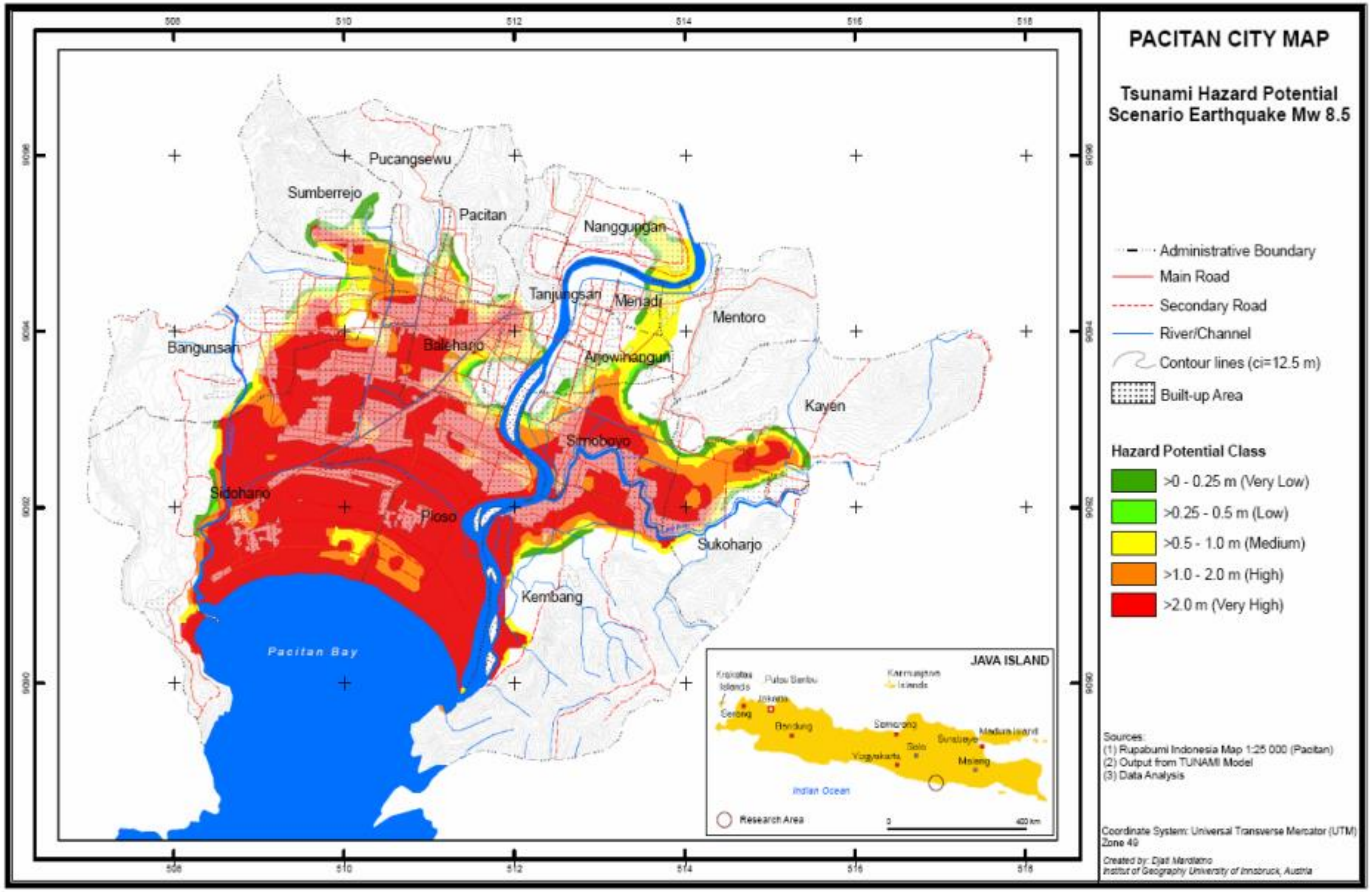
(Source : Mardiatno, 2008a)

Appendix 4. Figure of Pacitan Landform



(Source : Mardiatno, 2008a)

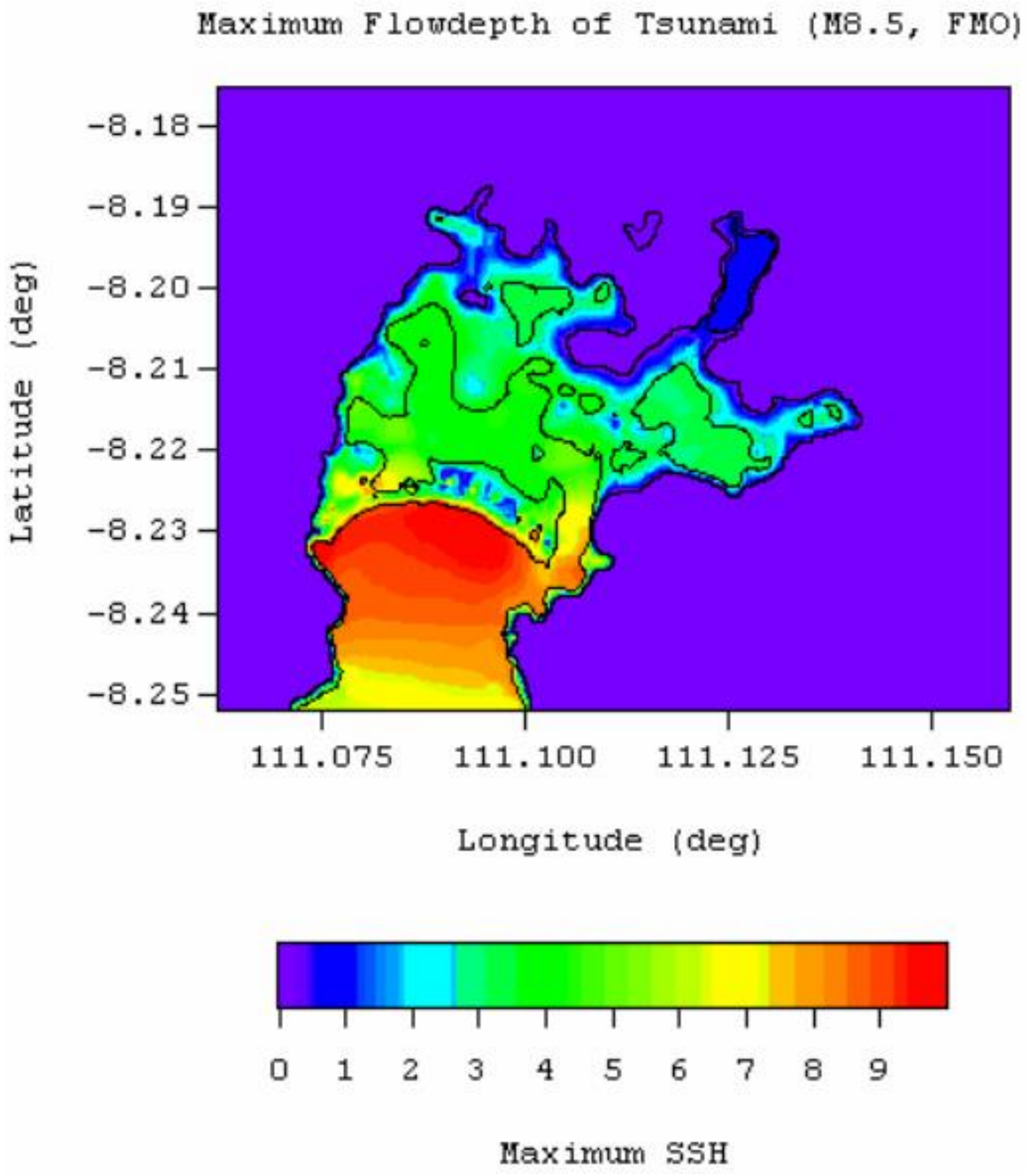
Appendix 5. Figure of Pacitan Tsunami Hazard Potential Scenario Earhquake Mw=8,5



(Source : Mardiatno, 2008a)

Appendix 6. Figure of Maximum Flow Depth

in Earthquake Scenario Mw=8.5



(Source : Mardiatno, 2008a)

Appendix 7. List of Interview Questions

1. Day/Date/Location : _____________
2. Name : ___________________________
3. Origin Area/Vehicle : ______________
4. Gender/Age : ______________
5. Knowledge about tsunami potential hazard in tourism location : (Yes/No)
6. Knowledge about tsunami evacuation sign in tourism area: (Yes/No)
7. Knowledge about the existing evacuation location : (Yes/No)
8. Knowledge about the route to go to evacuation location : (Yes/No)
9. Knowledge about time to evacuate
   a. 0-10 minutes
   b. 10-20 minutes
   c. 20-30 minutes
   d. > 30 minutes
   e. Others
10. Knowledge about the minimum elevation to safe life from tsunami
    a. 0-10 m
    b. 10-20 m
    c. 20-30 m
    d. >30 m
    e. Others
11. When you hear sirine sound, what will you do ?
    a. Quiet, look at other people response first
    b. Directly evacuate
12. Tools for evacuation
    a. Walk/Run
    b. Bicycle
    c. Motorbike
    d. Car
    e. Others
13. In evacuation process, which method that will you choose
    a. Looking for route based on own knowledge
    b. Follow crowded
14. Times visiting tourism area
    a. 1st time
    b. 2nd time
    c. 3rd time
    d. 4th time
    e. More than 4

Appendix 8. Interview Result in Pancer Door Beach

No	Name	Age Group	Time Visiting	Vehicle	Origin From	PROVINCE	Knowledge about		Ev Time	Tools for Ev	Ev Method	Map option	Human Behavior
							Hazard	Ev Sign	Minute			1st Answer	
Saturday, 22 Oct 2016													
1	Mrs Marji	26 until 30	>4	Car	Kebonagung, Pacitan	EAST JAVA	Yes	Yes	Dont Know	Car	Own Knowledge	A	Homing Behavior
2	Ms Ela	26 until 30	1	-	Finland	FINLAND	Yes	Yes	Dont Know	Motorcycle	Follow Crowded	Stay in Hotel	Proximal Characteristic
3	Ms Estelle	31 until 35	1	-	France	FRANCE	No	No	Dont Know	Motorcycle	Follow Crowded	B	Proximal Characteristic
4	Ms Elvira	31 until 35	1	-	Spain	SPAIN	Yes	Yes	Dont Know	Walk or Run	Follow Crowded	B	Proximal Characteristic
5	Ms Anna	21 until 25	>4	Motorcycle	Bandar, Pacitan	EAST JAVA	Yes	Yes	20	Motorcycle	Own Knowledge	B	Homing Behavior
6	Ms Leli	21 until 25	>4	Motorcycle	Punung, Pacitan	EAST JAVA	Yes	Yes	20	Motorcycle	Own Knowledge	B	Proximal Characteristic
7	Mr Philip	51 until 55	2	-	France	FRANCE	Yes	Yes	Dont Know	Motorcycle	Follow Crowded	B	Proximal Characteristic
8	Mrs Ema	51 until 55	2	-	Netherland	NETHERLAND	Yes	Yes	15	Motorcycle	Follow Crowded	B	Proximal Characteristic
Sunday, 1 January 2017													
1	Mrs Herna	46 until 50	>4	Motorcycle	Sirnoboyo, Pacitan	EAST JAVA	Yes	Yes	Dont Know	Motorcycle	Own Knowledge	A	Homing Behavior
2	Mrs Anik	51 until 55	1	Motorcycle	Kayen, Pacitan	EAST JAVA	No	No	Dont Know	Motorcycle	Own Knowledge	A	Homing Behavior
3	Mrs Fitri	41 until 45	1	Motorcycle	Sukoharjo	CENTRAL JAVA	Yes	No	Dont Know	Motorcycle	Own Knowledge	Go to the City	Homing Behavior
4	Ms Atin	21 until 25	>4	Motorcycle	Pacitan Kota	EAST JAVA	No	No	Dont Know	Walk/Run	Own Knowledge	Go to the City	Homing Behavior
5	Ms Aca	21 until 25	>4	Motorcycle	Pacitan Kota	EAST JAVA	No	No	Dont Know	Walk/Run	Own Knowledge	Go to the City	Homing Behavior
6	Ms Rina	21 until 25	>4	Motorcycle	Pacitan Kota	EAST JAVA	No	Yes	Dont Know	Walk/Run	Own Knowledge	Go to the City	Homing Behavior
7	Mr Sam	31 until 35	>4	Motorcycle	Pacitan Kota	EAST JAVA	No	No	5	Walk/Run	Own Knowledge	Go to the City	Homing Behavior

Appendix 9. Interview Result in Teleng Ria Beach

No	Name	Age Group	Time Visitin	Vehicle	Origin From	PROVINCE	Knowledge :		Ev Time	Tools for Ev	Ev Method	Map option	Human Behavior
							Hazard	Ev Sign	(minutes)				
Saturday, 22 October 2016													
1	Mrs Nur Cadika	51 until 55	1	Bus	Klaten	CENTRAL JAVA	No	Yes	5	Bus	Follow Crowded	B	Proximal Characteristic
2	Ms Annisa Azahra	16 until 20	1	Car	Klaten	CENTRAL JAVA	No	No	Dont Know	Car	Own Knowledge	C	Homing Behavior
3	Mrs Wiwik	36 until 40	3	Car	Madiun	EAST JAVA	No	No	Dont Know	Car	Own Knowledge	C	Homing Behavior
4	Mrs Watik	56 until 60	2	Car	Madiun	EAST JAVA	No	No	5	Car	Own Knowledge	C	Homing Behavior
5	Mrs Narti	46 until 50	1	Bus	Wonogiri	CENTRAL JAVA	No	No	Dont Know	Bus	Own Knowledge	C	Homing Behavior
6	Mrs Sumiyati	46 until 50	1	Bus	Wonogiri	CENTRAL JAVA	No	No	Dont Know	Bus	Own Knowledge	C	Homing Behavior
7	Mrs Sumiyarsih	46 until 50	1	Bus	Wonogiri	CENTRAL JAVA	No	No	Dont Know	Bus	Own Knowledge	C	Homing Behavior
Sunday, 25 December 2016													
8	Ms Norma	16 until 20	1	Car	Klaten	CENTRAL JAVA	No	No	Dont Know	Walk/Run	Own Knowledge	B	Proximal Characteristic
9	Ms Resita Reni	21 until 25	1	Bus	Klaten	CENTRAL JAVA	No	No	Dont Know	Bus	Own Knowledge	C	Homing Behavior
10	Ms Lilik	11 until 15	1	Car	Klaten	CENTRAL JAVA	No	No	Dont Know	Walk/Run	Own Knowledge	B	Proximal Characteristic
11	Ms Sekar	11 until 15	1	Bus	Klaten	CENTRAL JAVA	No	No	20	Walk/Run	Follow Crowded	B	Proximal Characteristic
12	Mrs Erva Nur	36 until 40	4	Car	Nganjuk	EAST JAVA	Yes	No	Dont Know	Walk/Run	Own Knowledge	B	Proximal Characteristic
13	Mrs Sri Astuti	41 until 45	2	Motorcycle	Giriwoyo, Pacitan	EAST JAVA	No	No	Dont Know	Motorcycle	Follow Crowded	B	Proximal Characteristic
14	Mrs Lasmi	51 until 55	>4	Car	Nganjuk	EAST JAVA	No	No	15	Car	Own Knowledge	B	Proximal Characteristic
15	Mrs Yanti	36 until 40	1	Car	Boyolali	CENTRAL JAVA	No	No	Dont Know	Walk/Run	Own Knowledge	B	Proximal Characteristic
16	Mrs Yuli	36 until 40	1	Car	Sukoharjo	CENTRAL JAVA	No	No	Dont Know	Walk/Run	Own Knowledge	C	Homing Behavior
17	Mrs Joko	36 until 40	1	Car	Sukoharjo	CENTRAL JAVA	No	No	Dont Know	Walk/Run	Own Knowledge	C	Homing Behavior
18	Mrs Erliana	31 until 35	1	Car	Ponorogo	EAST JAVA	No	No	10	Car	Own Knowledge	A	Homing Behavior
19	Ms Vici	26 until 30	2	Car	Madiun	EAST JAVA	No	No	5	Walk/Run	Own Knowledge	C	Homing Behavior
20	Mrs Puji	36 until 40	2	Car	Ponorogo	EAST JAVA	No	No	Dont Know	Walk/Run	Own Knowledge	B	Proximal Characteristic
21	Mrs Ratih	36 until 40	1	Car	Magetan	EAST JAVA	Yes	No	Dont Know	Walk/Run	Own Knowledge	A	Homing Behavior
22	Mrs Sutiyem	71 until 75	1	Car	Magetan	EAST JAVA	No	No	Dont Know	Walk/Run	Own Knowledge	A	Homing Behavior
23	Mrs Wati	36 until 40	3	Car	Riau	SUMATRA	No	No	30	Car	Own Knowledge	B	Proximal Characteristic

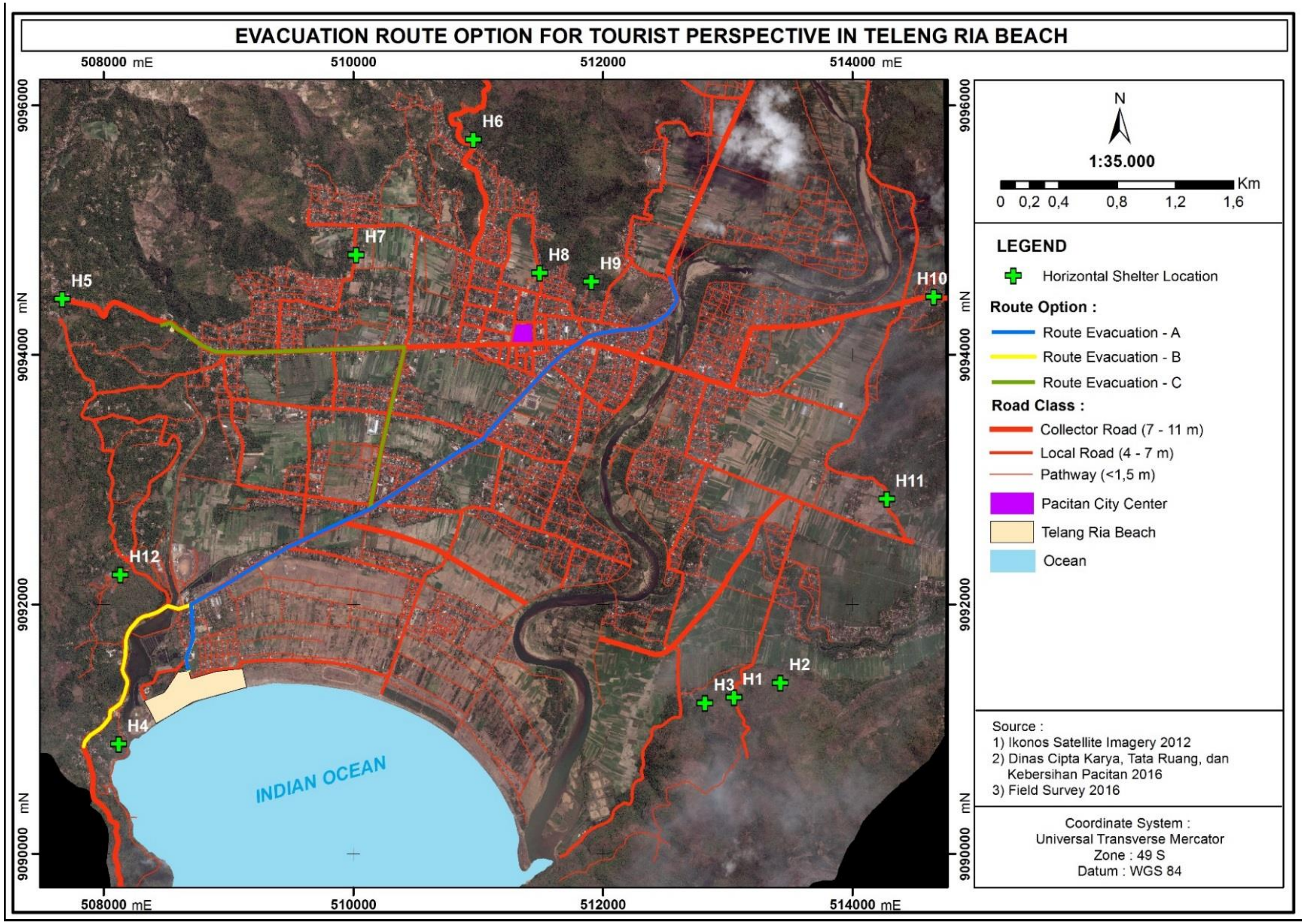
No	Name	Age Group	Time Visitin	Vehicle	Origin From	PROVINCE	Knowledge :		Ev Time	Tools for	Ev Method	Map option	Human Behavior
							Hazard	Ev Sign	(minutes)	Ev			
Saturday, 31 December 2016													
24	Mrs Wati	36 until 40	1	Car	Sragen	CENTRAL JAVA	No	No	Dont Know	Walk/Run	Follow Crowded	Confused	Straight Characteristic
25	Ms Asih	36 until 40	2	Car	Ngawi	EAST JAVA	No	No	Dont Know	Car	Own Knowledge	A	Homing Behavior
26	Mr Iwan	36 until 40	1	Car	Jakarta	JAKARTA	Yes	No	30	Car	Own Knowledge	C	Homing Behavior
27	Ms Erita	16 until 20	3	Car	Ponorogo	EAST JAVA	Yes	No	5	Walk/Run	Own Knowledge	B	Proximal Characteristic
28	Ms Ratih	16 until 20	3	Car	Ponorogo	EAST JAVA	Yes	No	10	Walk/Run	Own Knowledge	B	Proximal Characteristic
29	Mr Sendy	21 until 25	2	Car	Ponorogo	EAST JAVA	Yes	No	5	Walk/Run	Own Knowledge	B	Proximal Characteristic
30	Mrs Sriyati	41 until 45	>4	Car	Solo	CENTRAL JAVA	Yes	No	30	Walk/Run	Own Knowledge	C	Homing Behavior
31	Mrs Nurul	46 until 50	>4	Car	Ponorogo	EAST JAVA	No	No	3	Walk/Run	Follow Crowded	Confused	Straight Characteristic
32	Ms Yani	36 until 40	>4	Car	Madiun	EAST JAVA	No	No	15	Walk/Run	Own Knowledge	A	Homing Behavior
33	Mrs Sulistyowat	46 until 50	1	Car	Karanganyar	CENTRAL JAVA	No	No	Dont Know	Walk/Run	Follow Crowded	Confused	Straight Characteristic
34	Mrs Septi	21 until 25	>4	Motorcycle	Wonogiri	CENTRAL JAVA	No	No	3	Walk/Run	Follow Crowded	Confused	Straight Characteristic
35	Ms Ayu	21 until 25	>4	Motorcycle	Wonogiri	CENTRAL JAVA	No	No	2	Walk/Run	Follow Crowded	Confused	Straight Characteristic
36	Mrs Dian	31 until 35	>4	Car	Ponorogo	EAST JAVA	No	Yes	30	Walk/Run	Own Knowledge	A	Homing Behavior
37	Ms Brili	21 until 25	1	Car	Ngawi	EAST JAVA	Yes	No	10	Car	Own Knowledge	A	Homing Behavior
38	Ms Nadia	16 until 20	1	Bus	Solo	CENTRAL JAVA	Yes	No	Dont Know	Walk/Run	Own Knowledge	C	Homing Behavior
39	Ms Zahro	16 until 20	1	Bus	Solo	CENTRAL JAVA	No	No	Dont Know	Walk/Run	Own Knowledge	C	Homing Behavior
40	Ms Zhafira	16 until 20	1	Bus	Solo	CENTRAL JAVA	No	No	Dont Know	Walk/Run	Own Knowledge	C	Homing Behavior
41	Ms Ana	16 until 20	1	Bus	Solo	CENTRAL JAVA	No	No	Dont Know	Walk/Run	Own Knowledge	C	Homing Behavior
42	Mrs Novi	16 until 20	4	Car	Madiun	EAST JAVA	No	Yes	60	Walk/Run	Own Knowledge	A	Homing Behavior
43	Ms IIS	16 until 20	1	Car	Ngawi	EAST JAVA	Yes	No	5	Walk/Run	Follow Crowded	Confused	Straight Characteristic
44	Ms Lilis	16 until 20	1	Car	Ngawi	EAST JAVA	No	No	10	Walk/Run	Follow Crowded	Confused	Straight Characteristic
45	Mrs Titin	51 until 55	>4	Motorcycle	Jogja	JOGJA	Yes	Yes	20	Motorcycle	Own Knowledge	C	Homing Behavior
46	Mrs Neti	31 until 35	1	Car	Wonogiri	CENTRAL JAVA	No	Yes	Dont Know	Car	Own Knowledge	C	Homing Behavior

Sunday, 1 January 2017													
47	Ms Cindy Larasat	16 until 20	1	Motorcycle	Madiun	EAST JAVA	Yes	Yes	Dont Know	Motorcycle	Own Knowledge	A	Homing Behavior
48	Mrs Sugi	51 until 55	1	Bus	Baturetno	CENTRAL JAVA	No	No	Dont Know	Bus	Follow Crowded	Confused	Straight Characteristic
49	Mrs Wati	36 until 40	2	Car	Magetan	EAST JAVA	Yes	No	Dont Know	Walk/Run	Own Knowledge	A	Homing Behavior
50	Mrs Susi	31 until 35	>4	Car	Ponorogo	EAST JAVA	Yes	No	Dont Know	Walk/Run	Own Knowledge	B	Proximal Characteristic
51	Mrs Sindi	16 until 20	>4	Motorcycle	Ponorogo	EAST JAVA	No	No	20	Walk/Run	Own Knowledge	A	Homing Behavior
52	Mr Nuryono	36 until 40	>4	Car	Wonogiri	CENTRAL JAVA	No	No	Dont Know	Walk/Run	Own Knowledge	C	Homing Behavior
53	Mrs Bety	46 until 50	>4	Car	Wonogiri	CENTRAL JAVA	No	No	Dont Know	Walk/Run	Own Knowledge	C	Homing Behavior
54	Mrs Menik	41 until 45	>4	Car	Solo	CENTRAL JAVA	No	Yes	5	Walk/Run	Own Knowledge	Go to Pacitan City	Homing Behavior
55	Ms Ajeng	16 until 20	>4	Motorcycle	Baleharjo, Pacitan	EAST JAVA	Yes	Yes	Dont Know	Motorcycle	Own Knowledge	Go to Pacitan City	Homing Behavior
56	Ms Dewi	16 until 20	>4	Car	Punung, Pacitan	EAST JAVA	No	No	Dont Know	Car	Own Knowledge	C	Homing Behavior
57	Ms Reni	16 until 20	>4	Car	Punung, Pacitan	EAST JAVA	No	No	Dont Know	Car	Own Knowledge	C	Homing Behavior
58	Mrs Ririn	31 until 35	2	Car	Ponorogo	EAST JAVA	Yes	Yes	30	Walk/Run	Follow Crowded	Confused	Straight Characteristic
59	Ms Santi	31 until 35	>4	Car	Wonogiri	CENTRAL JAVA	No	No	30	Car	Own Knowledge	C	Homing Behavior
60	Ms Niken	36 until 40	3	Motorcycle	Ponorogo	EAST JAVA	Yes	Yes	30	Walk/Run	Own Knowledge	A	Homing Behavior
61	Ms Amalia	16 until 20	2	Car	Solo	CENTRAL JAVA	No	No	Dont Know	Walk/Run	Own Knowledge	C	Homing Behavior
62	Ms Tutut	16 until 20	2	Motorcycle	Ponorogo	EAST JAVA	Yes	No	Dont Know	Motorcycle	Own Knowledge	A	Homing Behavior
63	Mrs Lilik Purwat	36 until 40	1	Motorcycle	Ngawi	EAST JAVA	Yes	No	5	Motorcycle	Own Knowledge	B	Proximal Characteristic
64	Mrs Mini	41 until 45	1	Motorcycle	Tangerang	WEST JAVA	No	No	30	Walk/Run	Own Knowledge	B	Proximal Characteristic
65	Mrs Sulistyowat	51 until 55	4	Car	Magetan	EAST JAVA	No	No	Dont Know	Walk/Run	Own Knowledge	Go to Pacitan City	Homing Behavior
66	Mrs Eny	41 until 45	1	Bus	Sambungmacan	CENTRAL JAVA	No	No	Dont Know	Walk/Run	Follow Crowded	Confused	Straight Characteristic
67	Ms Lilis	16 until 20	3	Motorcycle	Bandar	EAST JAVA	No	No	5	Walk/Run	Own Knowledge	C	Homing Behavior
68	Mrs Lilik Indriya	11 until 15	1	Car	Boyolali	CENTRAL JAVA	No	No	5	Car	Own Knowledge	C	Homing Behavior
69	Ms Erlina	16 until 20	1	Car	Solo	CENTRAL JAVA	No	No	10	Walk/Run	Own Knowledge	Go to Pacitan City	Homing Behavior
70	Ms Jenia	11 until 15	1	Car	Solo	CENTRAL JAVA	No	No	10	Walk/Run	Own Knowledge	Go to Pacitan City	Homing Behavior
71	Ms Rita	11 until 15	3	Car	Gunungkidul	JOGJA	No	No	10	Walk/Run	Own Knowledge	C	Homing Behavior
72	Ms IIs	11 until 15	2	Car	Gunungkidul	JOGJA	No	No	30	Walk/Run	Own Knowledge	C	Homing Behavior

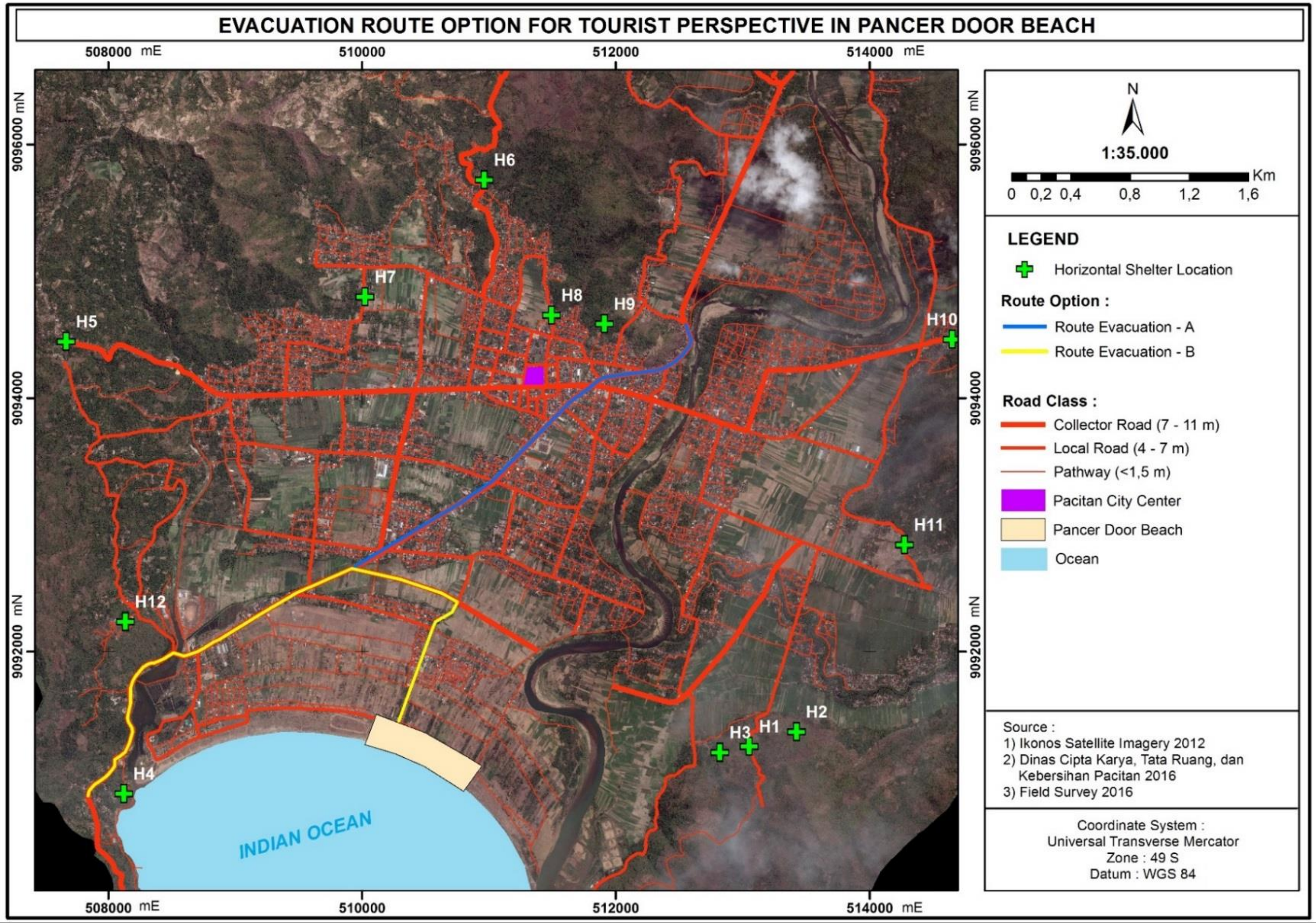
Appendix 10. Table of Respondent Origin Area

Origin From	Teleng Ria Beach	Pancer Door Beach
West Java	1	-
Central Java	32	1
East Java	34	9
Jogja	3	-
Sumatra	1	-
Jakarta	1	-
Finland	-	1
France	-	2
Spain	-	1
Netherland	-	1
TOTAL	**72**	**15**

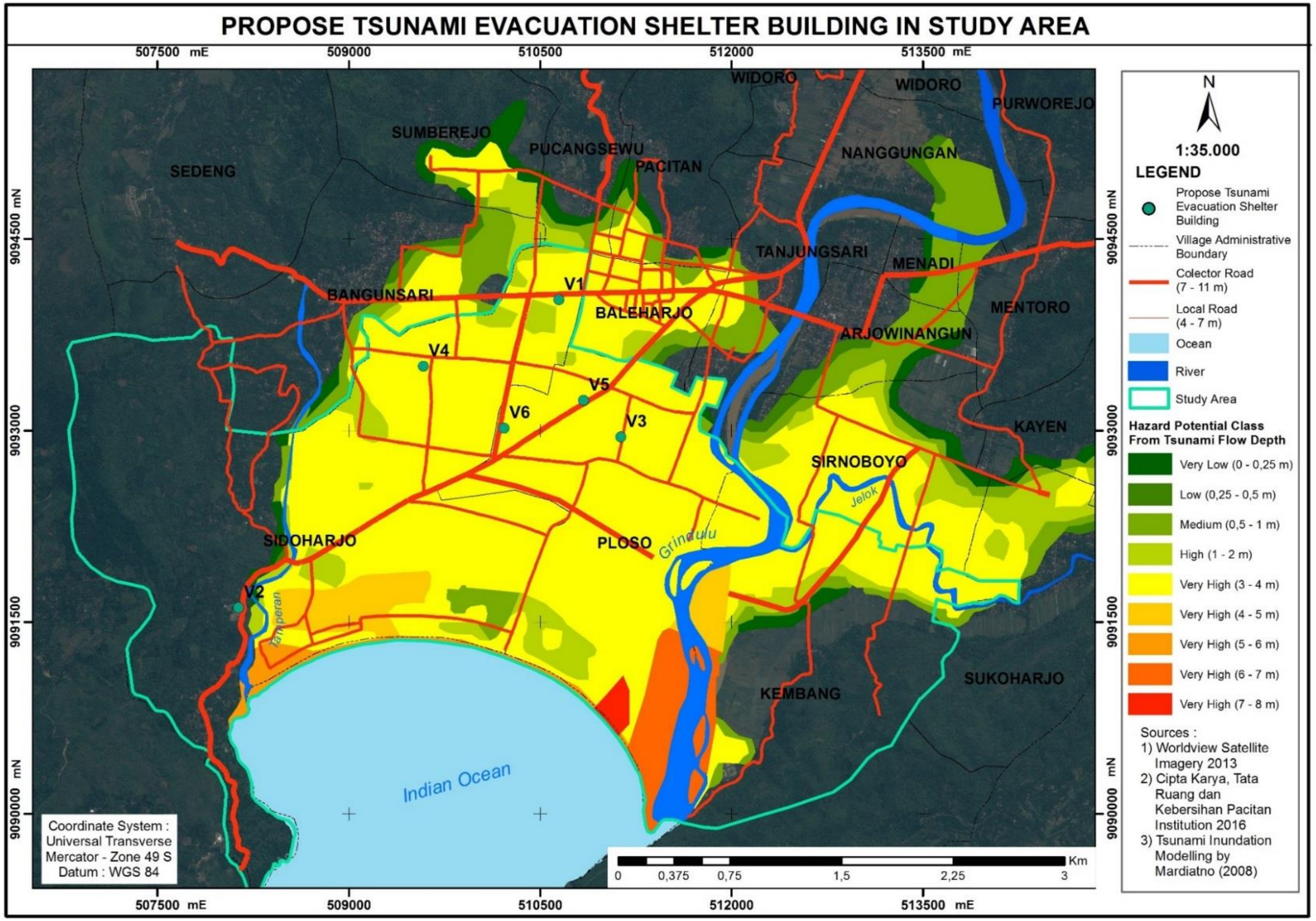
Appendix 11. Figure of Evacuation Route Option in Teleng Ria (Source : Data Analysis, 2016)



Appendix 12. Figure of Evacuation Route Option in Pancer Door (Source : Data Analysis, 2016)



Appendix 13. Figure of Propose Tsunami Evacuation Shelter Building in Study Area based on Tsunami Flow Depth from Mardiatno (2008)



Appendix 14. Table of Hotel and Homestay Scoring Result

No	Name	From Shore	From River	Number of Floor	Terrain Elevation (masl)	Score from Shore	Score from River	Score Floor	Score Elevation	TOTAL Score
1	Rajawali Hotel	403 m	290 m from Tamperan	2	10	1	1	1	1	4
2	Bali Asri Hotel	2783 m	2009 m from Grindulu	2	10	3	3	1	1	8
3	Srikandi Hotel	2831 m	1900 m from Grindulu	3	10	3	2	2	1	8
4	Wijaya Hotel	3596 m	71 m from Grindulu	2	15	3	0	1	2	6
5	Kraton Mas Syariah Guest House	2263 m	1579 m from Tamperan	2	10	3	2	1	1	7
6	Anugerah Jaya Homestay	220 m	1427 m from Tamperan	2	5	1	2	1	0	4
7	Simple Homestay	220 m	1422 m from Tamperan	2	5	1	2	1	0	4
8	Harry's Ocean Homestay	220 m	1854 m from Grindulu	2	5	1	2	1	0	4
9	Manguntur Homestay	220 m	1589 m from Tamperan	2	5	1	2	1	0	4
10	Graha Prima Hotel	671 m	78 m from Tamperan	5	30	1	0	3	3	7

Note :

Scoring system referred to section 4.2.3, present relative comparison. 3=High, 2=Medium, 1=Low, 0=Very Low

Total Score = Score from Shore + Score from River + Score Floor + Score Elevation

The biggest numbet of total score means the priority building

Appendix 15. Table of Public Facility Scoring Result

No	Description	From Shore	From River	Number of Floor	Terrain Elevation (masl)	Score ftom Shore	Score from River	Score Floor	Score Elevation	TOTAL Score
1	SMK N 2 PACITAN (school)	2140 m	833 m from Tamperan	3	10	3	1	2	1	7
2	SMK N 1 PACITAN (school)	1648 m	1645 m from Tamperan	2	10	2	2	1	1	6
3	SMA N 1 PACITAN (school)	1738 m	1746 m from Grindulu	2	10	2	2	1	1	6
4	SMK N 3 PACITAN (school)	1933 m	1706 m from Grindulu	2	10	2	2	1	1	6
5	MASJID NURUL IMAN (mosque)	1867 m	871 m from Grindulu	2	10	2	1	1	1	5
6	STKIP PGRI PACITAN (school)	2991 m	827 m from Grindulu	4	10	3	1	3	1	8
7	MI N SIDOHARJO (school)	844 m	169 m from Tamperan	2	10	1	0	1	1	3
8	SMK BINA KARYA (school)	980 m	643 m from Tamperan	2	10	1	1	1	1	4
9	MAN PACITAN (school)	2105 m	1118 m from Grindulu	2	10	3	2	1	1	7

Note :

Scoring system referred to section 4.2.3, present relative comparison. 3=High, 2=Medium, 1=Low, 0=Very Low

Total Score = Score from Shore + Score from River + Score Floor + Score Elevation

The biggest numbet of total score means the priority building

Appendix 16. Table of Pedestrial Travel Speeds Used in Previous Evacuation Analysis

Source	Original Description	Assigned Travel Speed Group	Travel Speed (m/s)
Lee et al., 2004 in C.-H. Huang & Wu, (2011)	Rush >50 : men, women Woman with a child <6 6 – 10 (children) Elder	Running Adult unimpaired Child Elderly	2.5 1.52 ; 1.38 0.72 1.12 0.92
Park, van de Lindt, Gupta, & Cox (2012)	Over 65 (old) Over 13 (young)	Elderly Adult unimpaired	1.253 1.509
Sugimoto et al (2003) and Muck (2008) in P. González-Riancho et.al (2013)	Fast population (adult) Slow population (elderly, children and disabled)	Adult unimpaired Adult impaired, elderly, child	1 0.7

Appendix 17. Table of The number of people on RW level of study area in 2015

Village	RW (Neighbourhood)	Men	Women	Total People	Household	Average people/ household
Ploso	1.Blumbang	299	292	591	176	3,4
	2.Temon	425	417	842	260	3,2
	3.Kebon	507	497	1004	303	3,3
	4.Krajan Lor	386	377	763	243	3,1
	5.Krajan Kidul	265	259	524	151	3,5
	6.Peden	268	262	530	167	3,2
	7.Ngampel	708	693	1401	478	2,9
	8.Barean	662	649	1311	403	3,3
TOTAL		**3520**	**3446**	**6966**	**2181**	**3**

Village	RW (Neighbourhood)	Men	Women	Total People	Household	Average people/ household
Sidoharjo	1.Bleber	267	322	589	142	4,1
	2.Tuban	500	541	1041	275	3,8
	3.Caruban	183	165	348	112	3,1
	4.Barak	325	340	665	174	3,8
	5.Balong	341	379	720	188	3,8
	6.Plelen	385	352	737	180	4,1
	7.Pojok	304	284	588	157	3,7
	8.Kriyan	223	207	430	146	2,9
	9.Jaten	291	277	568	172	3,3
	10.Tamperan	364	309	673	137	4,9
	11.Teleng	686	705	1391	367	3,8
	12.Barean	690	622	1312	339	3,9
TOTAL		**4559**	**4503**	**9062**	**2389**	**4**
Kembang	1. Bubakan	453	278	731	210	3,5
	2.Krajan	269	175	444	130	3,4
	3.Sedayu	313	200	513	143	3,6
	4.Karang	354	237	591	165	3,6
	5.Kiteran	194	130	324	87	3,7
TOTAL		**1583**	**1020**	**2603**	**735**	**4**
TOTAL POPULATION				**18631**		

Appendix 18. Table of tourist in Teleng Ria and Pancer Door beach in 2016

Month	**Teleng Ria Beach**		**Pancer Door Beach**	
	International	Local	International	Local
January	-	47973	10	973
February	-	21998	10	812
March	-	15556	40	1352
April	-	205509	40	7086
May	-	17405	10	3967
June	-	14773	10	984
July	-	63537	10	1637
August	-	15954	10	1570
TOTAL	**-**	**402705**	**140**	**18381**

(Source : Tourism Institution, September 2016)

Note : Fieldwork activity on September, therefore the number of tourist only on January until August

Appendix 19. Table of Hotel and Homestay Room Capacity 2016

No	Hotel and Homestay	Total Room	Room Capacity	No	Hotel and Homestay	Total Room	Room Capacity
1	Surfing Bay Cottages	31	62	12	Simple Homestay	13	26
2	Rajawali	20	60	13	Bundo Permai 2	9	18
3	Minang Permai 3	25	50	14	Pasanggrahan Bambu Kuning 2	10	23
4	Kampoeng Pacitan	13	26	15	Harry's Ocean Homestay	10	20
5	Purnama Guest House	7	14	16	Manguntur Homestay	15	45
6	Bali Asri	30	88	17	Minang Permai 2	10	10
7	Srikandi	20	47	18	Araya Homestay	9	21
8	Remaja	30	71	19	Dewi Sri Homestay	3	6
9	Kraton Mas Syariah Guest House	6	12	20	Graha Prima	37	111
10	Bundo Permai	10	20	21	Wijaya Mulia Guest House	10	20
11	Barehan Homestay	3	6	**TOTAL**			**756**

Appendixes 20. Table of Population Estimation in the House

Village	No	RW	TOTAL POPULATION	Household	Avg person/hh	Nr of house	Nr of hh/house	Nr of house	DAY	NIGHT
Sidoharjo	1	Bleber	589	142	4,1	145	1,0	10	20	41
	2	Tuban	1041	275	3,8	241	1,1	10	22	43
	3	Caruban	348	112	3,1	163	0,7	10	11	21
	4	Barak	665	174	3,8	161	1,1	10	21	41
	5	Balong	720	188	3,8	176	1,1	10	20	41
	6	Plelen	737	180	4,1	184	1,0	10	20	40
	7	Pojok	588	157	3,7	138	1,1	10	21	43
	8	Kriyan	430	146	2,9	70	2,1	10	31	61
	9	Jaten	568	172	3,3	90	1,9	10	32	63
	10	Tamperan	673	137	4,9	143	1,0	10	24	47
	11	Teleng	1391	367	3,8	315	1,2	10	22	44
	12	Barean	1312	339	3,9	372	0,9	10	18	35
Ploso	1	Blumbang	591	176	3,4	148	1,2	10	20	40
	2	Temon	842	260	3,2	258	1,0	10	16	33
	3	Kebon	1004	303	3,3	326	0,9	10	15	31
	4	Krajan Lor	763	243	3,1	209	1,2	10	18	37
	5	Krajan Kidul	524	151	3,5	135	1,1	10	19	39
	6	Peden	530	167	3,2	151	1,1	10	18	35
	7	Ngampel	1401	478	2,9	374	1,3	10	19	37
	8	Barean	1311	403	3,3	465	0,9	10	14	28
Kembang	1	Bubakan	731	210	3,5	214	1,0	10	17	34
	2	Krajan	444	130	3,4	100	1,3	10	22	44
	3	Sedayu	513	143	3,6	137	1,0	10	19	37
	4	Karang	591	165	3,6	165	1,0	10	18	36
	5	Kiteran	324	87	3,7	120	0,7	10	14	27

Note : Avg=Average hh=household Nr=number

Appendix 21. Table of Population Estimation in the Public Facility

DAY AND NIGHT WITHOUT CONSIDERING TOURIST IN SIDOHARJO

No	RW	Facility	Name	Area (m^2)	DAY	NIGHT
1	Bleber	Office	Pengadilan Agama	730	86	1
			Pengadilan Negeri	1671	197	1
			PLN	850	100	1
		School	SDIC Bleber	1406	387	1
			STITNU	1580	435	1
		Shop		4571	4	1
2	Tuban	Office	Ketahanan	954	112	1
			Desa	790	93	1
			Inspektorat	1405	165	1
			BPN	1446	170	1
			BPD	1106	130	1
			Telkom	716	84	1
		Hotel	Remaja		3	3
			Srikandi		3	3
			Bali Asri		3	3
			Kraton Mas Syariah		2	2
		Mosque		1143	64	1
		Shop		3689	4	1
3	Caruban	Office	Tanaman Pangan	1321	155	1
			Dinkes	988	116	1
			Kecamatan	998	117	1
			BAPEMAS	723	85	1
		Mosque		762	42	1
		School	SD Sidoharjo	1078	296	1
		Shop		999	4	1
4	Barak	School	TK Az Zalfa	1413	389	1
			Panti Sosial	793	218	1
			SMK N 2		1508	2
			Akademi Komunitas Negri		327	2
		Shop		1076	4	1
5	Balong	Office	Dishub	2536	298	1
			BPBD	1386	163	1
			KODIM	4757	560	1
		Mosque		602	33	1
		School	TK Hajar Aswad	845	232	1

			SD Alam		150	2
			SD Integral	147	40	1
			SMK N3		958	2
		Shop		1670	4	1
6	Plelen	Office	Kejaksaan	1857	218	1
		Mosque		232	13	1
		School	SMK Bina Karya		350	2
		Shop		1284	4	1
7	Pojok	Office	Bina Marga	4267	502	1
			Diknas	2267	267	1
		School	SMP N 3		490	2
			SMK N 2	1522	419	1
8	Kriyan	Mosque		165	9	1
9	Jaten	Office	Dinas Perhubungan	3068	361	1
		Mosque		342	19	1
		Shop		91	4	1
10	Tamperan	Shop		3004	4	1
		Hotel	Graha Prima		3	3
11	Teleng	Hotel	Surfing Bay		3	3
			Rajawali		3	3
			Minang 3		3	3
			Wijaya Guest House		3	3
			Araya Homestay		2	2
		Office	Balai Warga	153	18	1
			Dishub	1180	139	1
			Disbud	1533	180	1
			Polsek	172	20	1
			BULOG	6064	713	1
		Mosque		157	9	1
		School	MI	665	183	1
			MIN	904	249	1
			Dinas Perpustakaan	814	224	1
		Shop		10878	4	1
12	Barean	Office	AURI	1748	206	1
			BPJ	362	43	1
			Swasta	273	32	1
		Hotel	Barehan Homestay	169	2	2
			Anugrah Jaya Homestay	161	2	2
			Simple Homestay	104	3	3

		Manguntur Homestay	180	3	3
		Putra Tunggal	212	2	2
		Harry's Ocean Homestya	1751	2	2
	Shop		7746	4	1
	Mosque		333	19	1

DAY AND NIGHT WITH CONSIDERING TOURIST IN SIDOHARJO

No	Villages	Facility	Name	Room	Room Capacity	DAY	NIGHT
2	Tuban		Remaja	30	71	3	74
			Srikandi	20	47	3	50
			Bali Asri	30	88	3	91
		Hotel	Kraton Mas Syariah	6	12	2	14
10	Tamperan	Hotel	Graha Prima	37	111	3	114
11	Teleng		Surfing Bay	31	62	3	65
			Rajawali	20	60	3	63
			Minang 3	25	50	3	53
			Wijaya GH	10	20	3	23
		Hotel	Araya Hs	9	21	2	23
		Beach	Teleng Ria			1678	0
12	Barean		Barehan Hs	3	6	2	8
			Anugrah Jaya Hs	5	20	2	22
			Simple Hs	13	26	3	29
			Manguntur Hs	15	45	3	48
			Putra Tunggal	10	20	2	22
		Hotel	Harry's Ocean	10	20	2	22

DAY AND NIGHT WITHOUT CONSIDERING TOURIST IN PLOSO

No	Villages	Facility	Name	Area (m^2)	DAY	NIGHT
1	Blumbang	School	MAN		978	2
		Shop		1665	4	1
2	TEMON	Office	Kelurahan	787	93	1
			Perijinan	535	63	1
			Dinsos	628	74	1

			KPP	675	79	1
		School	TK Kelurahan	302	83	1
			SDN Ploso 1		962	1
		Mosque		1029	57	1
		Shop		3133	4	1
		Hotel	Bundo Permai		2	2
3	KEBON	Office		938	110	1
		Mosque		269	15	1
		School	MI		387	2
			SD N2	931	256	1
			SMK PGRI	3929	1080	1
			STKIP		1297	2
		Shop		3748	4	1
4	KRAJAN LOR	-	-		-	-
5	KRAJAN KIDUL	-	-		-	-
6	PEDEN	Mosque		461	26	1
		School	PonPes Al Anwar		350	2
7	NGAMPEL	Office	KODIM	1135	134	1
		School	MAN	1286	354	1
			Pendidikan Dasar	820	226	1
			SMA N 1		941	2
			SMK N 1		1691	2
			SMK N 3		958	2
		Hotel	Kampoeng Pacitan		3	3
			Purnama Guest House		2	2
		Mosque		678	38	1
		Shop		8710	4	1
8	BAREAN	Masjid		393	22	1

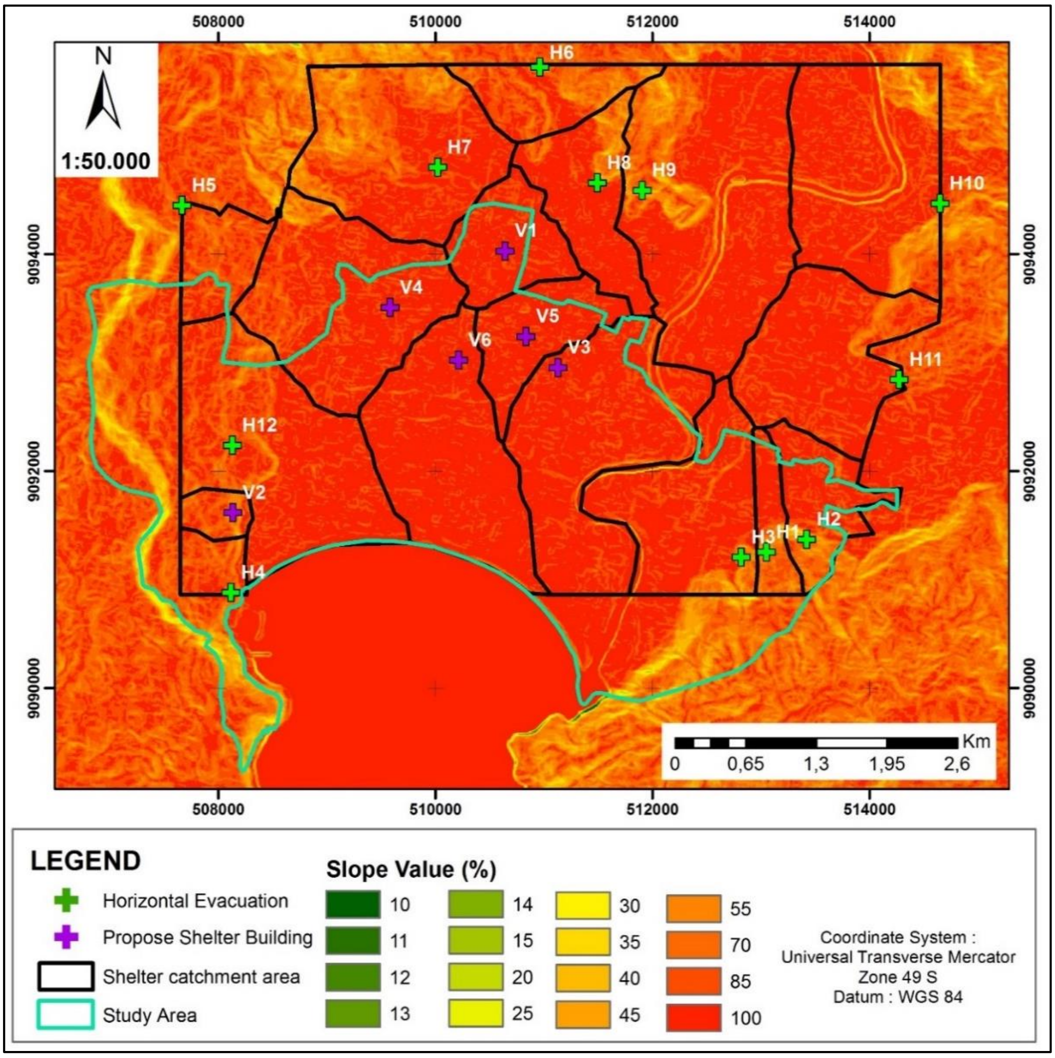
DAY AND NIGHT WITH CONSIDERING TOURIST IN PLOSO

No	Villages	Facility	Name	Room	Room Capacity	DAY	NIGHT
2	TEMON	Hotel	Bundo Permai	10	20	2	22
7	NGAMPEL	Hotel	Kampoeng	13	26	3	29
			Purnama Guest House	7	14	2	16
8	BAREAN	Beach				77	0

DAY AND NIGHT WITHOUT CONSIDERING TOURIST IN KEMBANG

No	Villages	Facility	Name	Area (m^2)	DAY	NIGHT
1	Bubakan	Mosque	Masjid	122	7	1
			Mushola	84	5	1
2	Krajan	Office	Desa	656	77	1
		School	SD	1175	323	1
3	Sedayu	-	-	-	-	-
4	Karang	Mosque		264	15	1
5	Kiteran	Mosque		228	13	1

Appendix 22. Figure of Slope Value



Note : Slope value in percentage based on slope classification from ADPC (2007) referred to table 4.3.

Appendix 23. Table of Shelter Ability in Different Scenario

Shelter ID	TEBC	Time (minutes)	Number of Population in Scenario			
			Day	Night	Day+ Tourist	Night+ Tourist
H1	647	**10**	7	14	7	14
		20	-	-	-	-
		30	4	7	4	7
		45	11	22	11	22
		60	-	-	-	-
		120	-	-	-	-
		TOTAL	**22**	**43**	**22**	**43**
H2	120	**10**	-	-	-	-
		20	-	-	-	-
		30	306	607	306	607
		45	198	364	198	364
		60	-	-	-	-
		120	-	-	-	-
		TOTAL	**504**	**971**	**504**	**971**
H3	120	**10**	18	36	18	36
		20	31	63	31	63
		30	44	89	44	89
		45	234	441	234	441
		60	515	229	515	229
		120	-	-	-	-
		TOTAL	**842**	**858**	**842**	**858**
H4	168	**10**	90	179	90	179
		20	62	110	62	110
		30	-	-	-	-
		45	-	-	-	-
		60	-	-	-	-
		120	-	-	-	-
		Undefined Area	166	329	166	329
		TOTAL	**318**	**618**	**318**	**618**
H12	7174	**10**	60	120	60	120
		20	166	328	166	328
		30	1023	529	1023	529
		45	1838	1281	3516	1494
		60	80	151	80	157
		120	356	89	356	89
		Undefined Area	153	51	153	171
		TOTAL	**3676**	**2549**	**5354**	**2888**
V1	301	**10**	1150	687	1180	893
		20	1662	790	1662	790

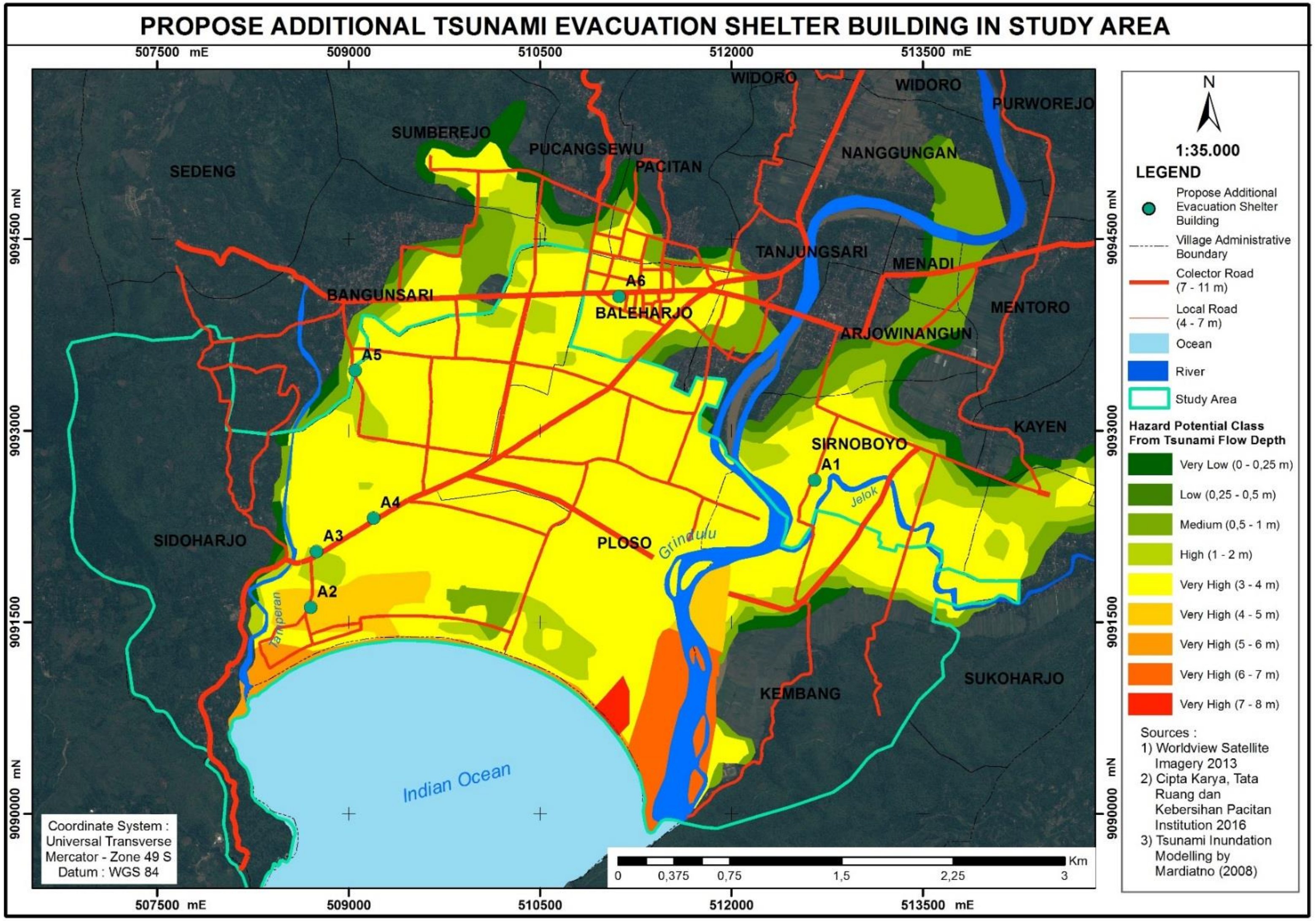
		30	200	142	200	142
		45	-	-	-	-
		60	-	-	-	-
		120	-	-	-	-
		TOTAL	**3012**	**1619**	**3012**	**1825**
V2	596	**10**	-	-	-	-
		20	50	86	50	197
		30	64	128	64	128
		45	-	-	-	-
		60	-	-	-	-
		120	-	-	-	-
		TOTAL	**114**	**214**	**114**	**214**
V3	289	**10**	2421	91	2421	91
		20	772	763	772	763
		30	1407	1224	1407	1224
		45	929	1860	929	1880
		60	203	403	203	403
		120	78	3	78	3
		TOTAL	**5810**	**4344**	**5810**	**4364**
V4	741	**10**	3267	481	3267	481
		20	1938	785	1938	785
		30	401	781	401	781
		45	21	42	21	42
		60	-	-	-	-
		120	-	-	-	-
		TOTAL	**5627**	**2089**	**5627**	**2089**
V5	91	**10**	1400	443	1400	443
		20	1875	1101	1875	1101
		30	242	478	242	478
		45	-	-	-	-
		60	-	-	-	-
		120	-	-	-	-
		TOTAL	**3517**	**2022**	**3517**	**2022**
V6	1026	**10**	-	-	-	-
		20	6070	900	6070	916
		30	312	599	312	637
		45	674	797	674	797
		60	593	1131	670	1262
		120	2	6	2	6
		TOTAL	**7651**	**3433**	**7728**	**3618**
TOTAL POPULATION			**31093**	**18769**	**32848**	**19510**

Note :

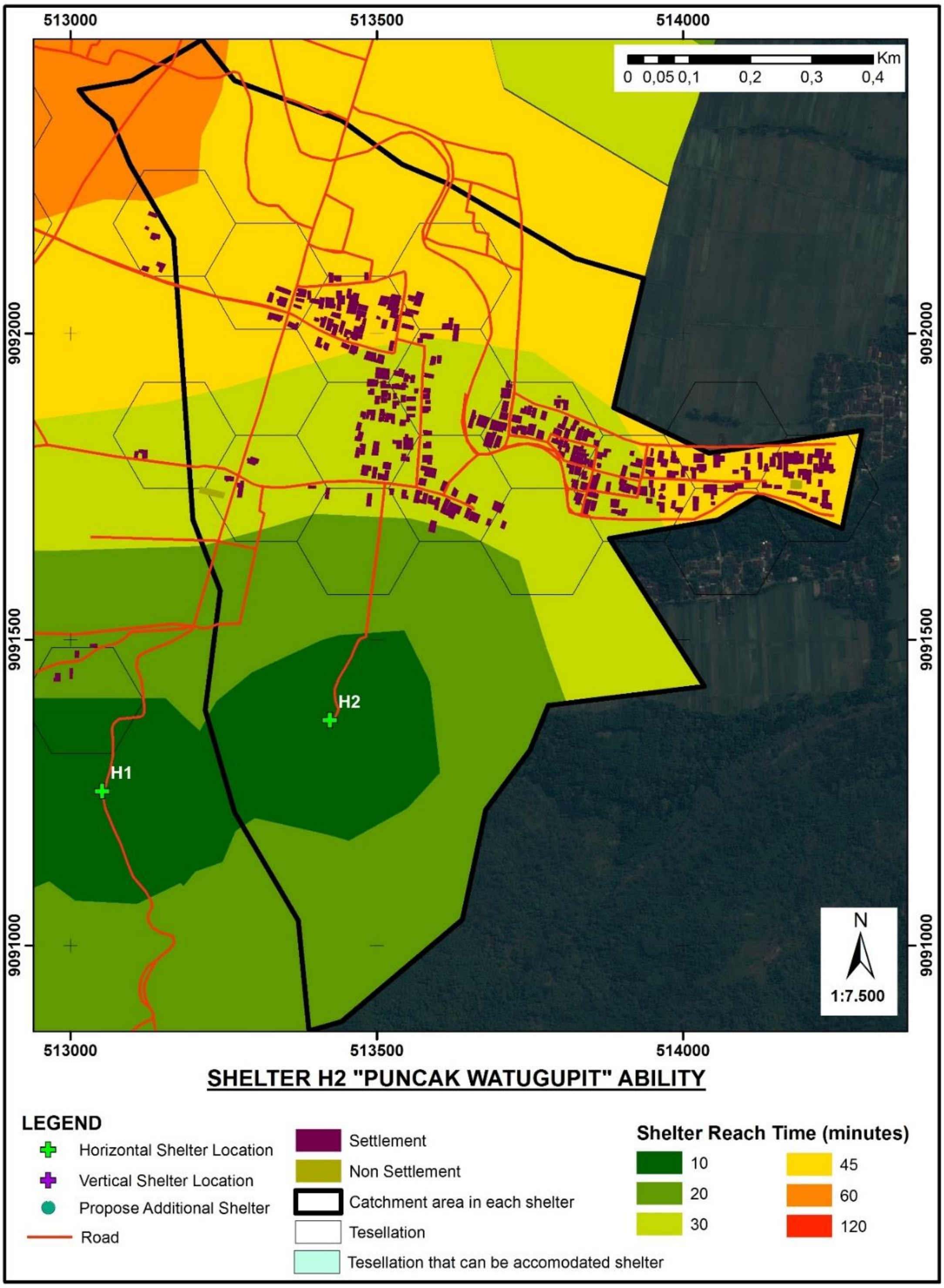
TEBC : Tsunami Evacuation Building Capacity Total : Total Population in Each Shelter

Undefined Area : An area outside catchment area but still inside study area

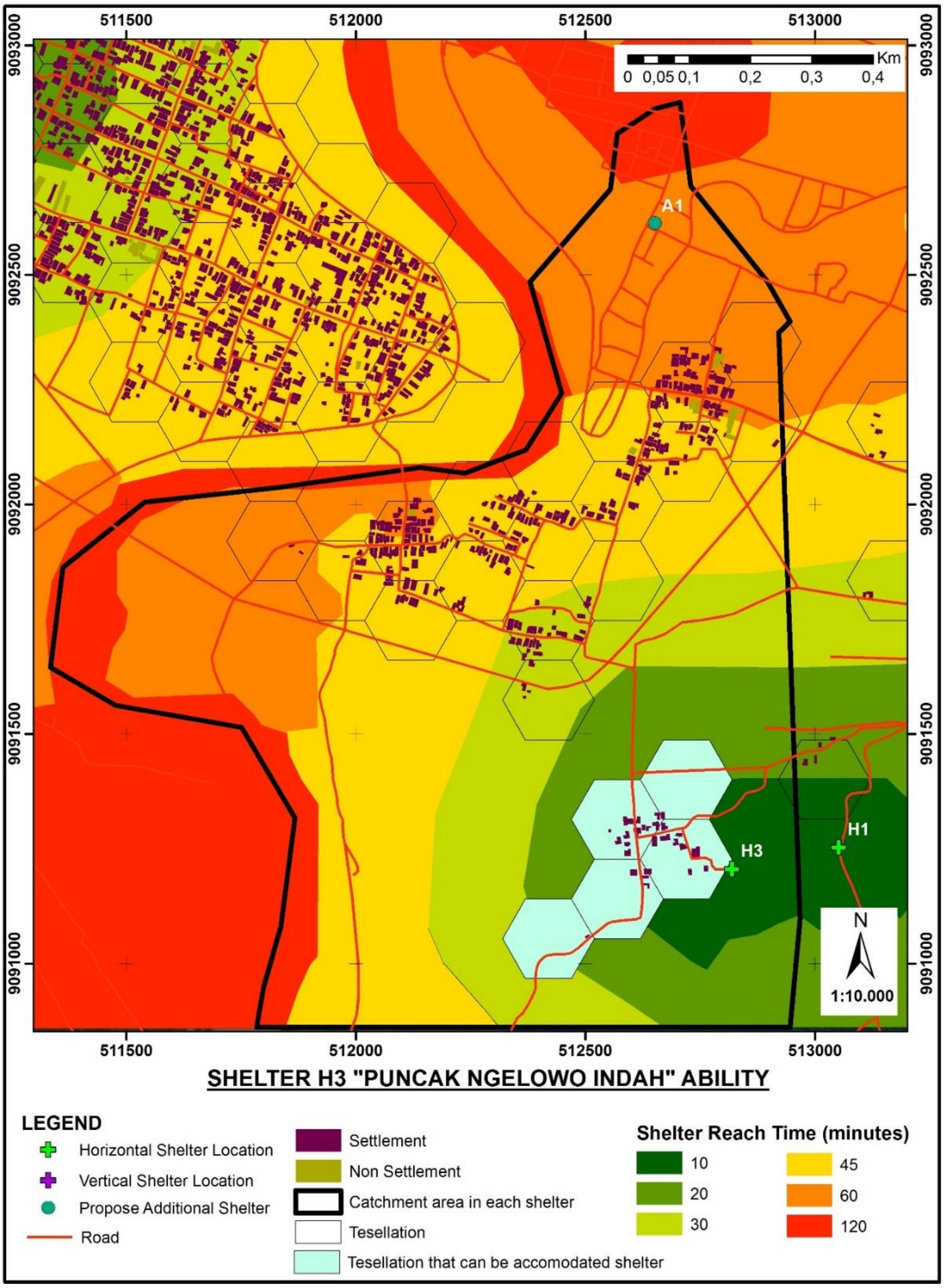
Appendix 24. Figure of Additional Propose Shelter Building



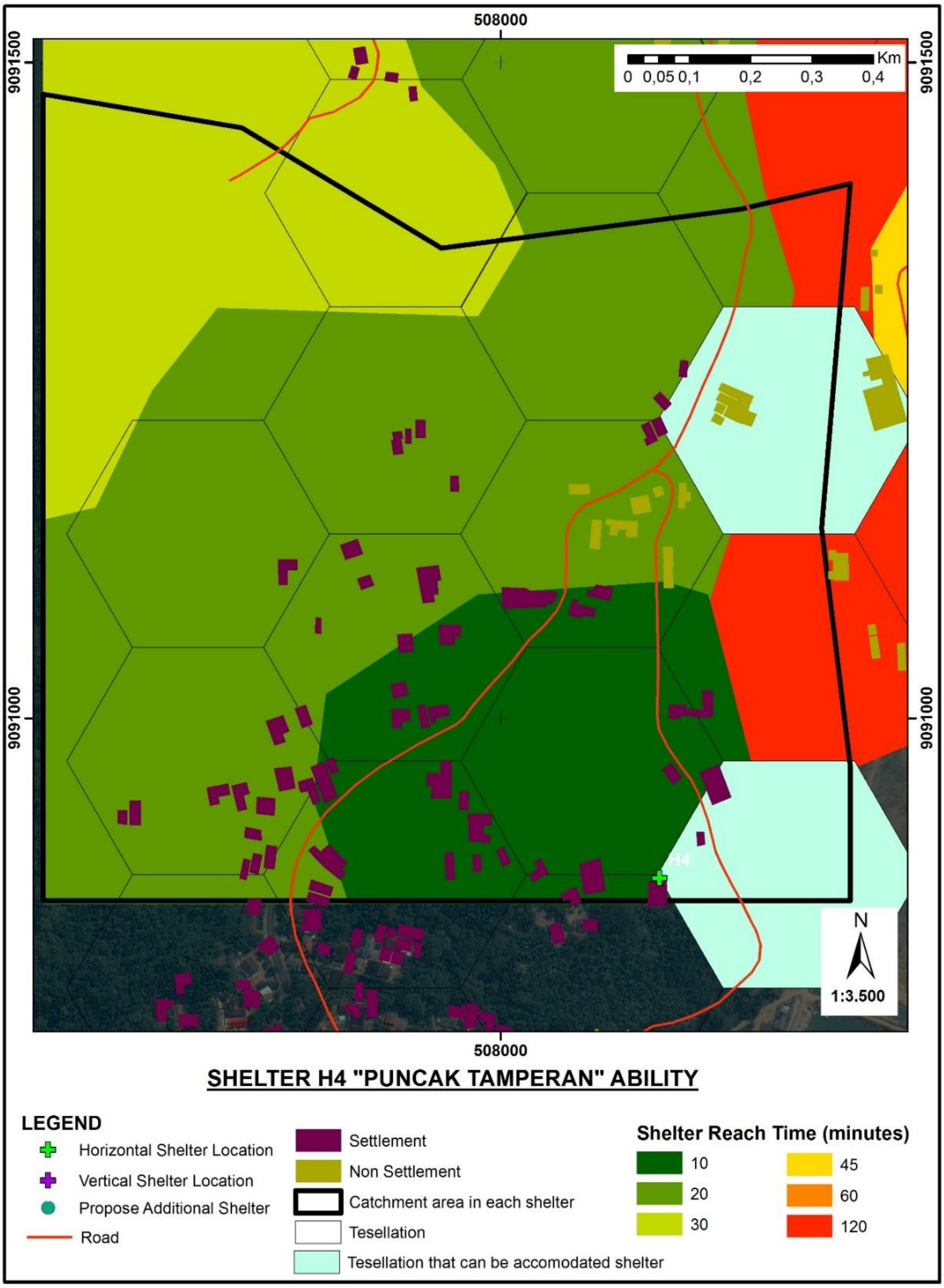
Appendix 25. Figure of Shelter H2 “Puncak Watugupit” Ability



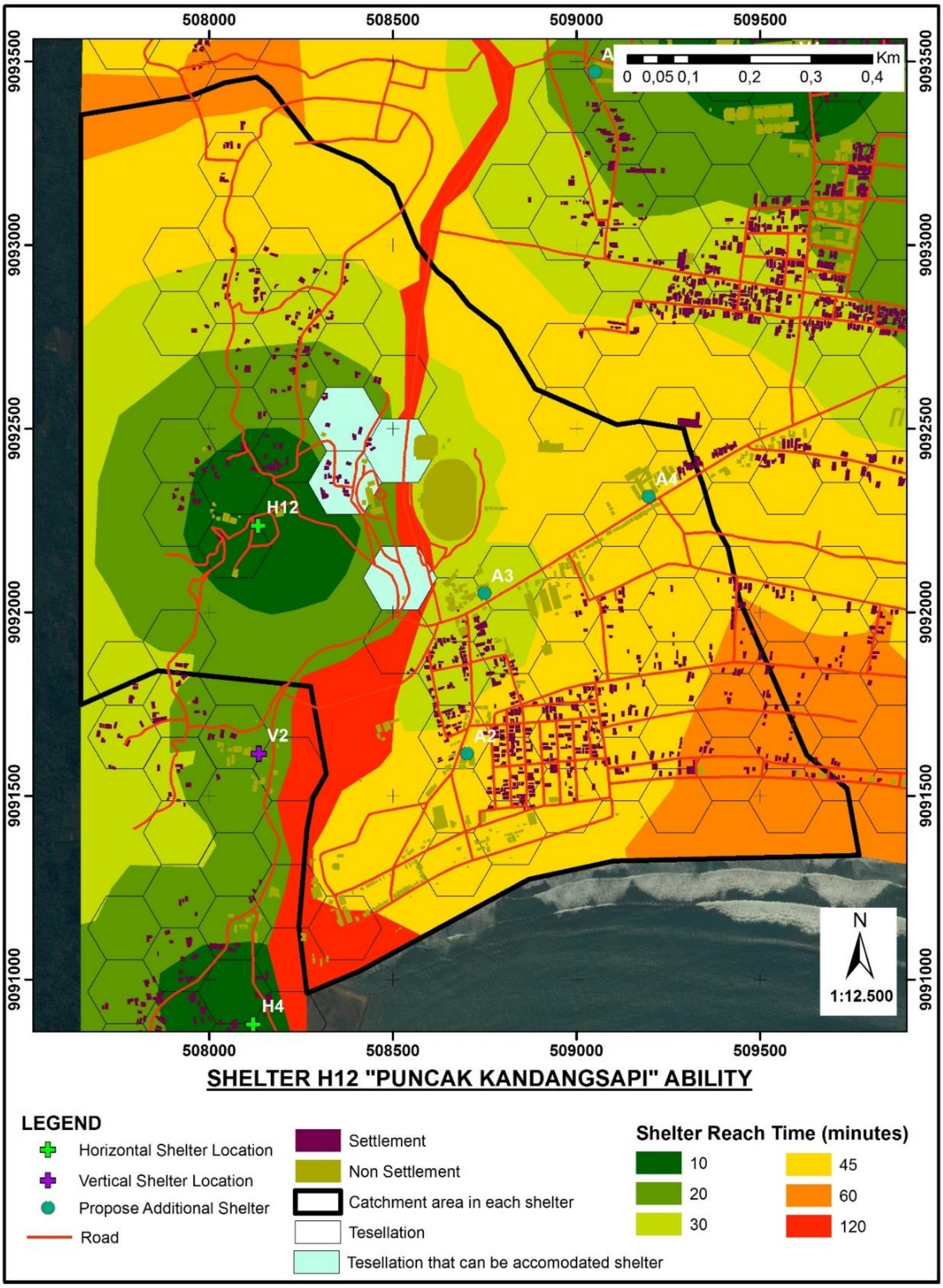
Appendix 26. Figure of Shelter H3 “Puncak Ngelowo Indah” Ability



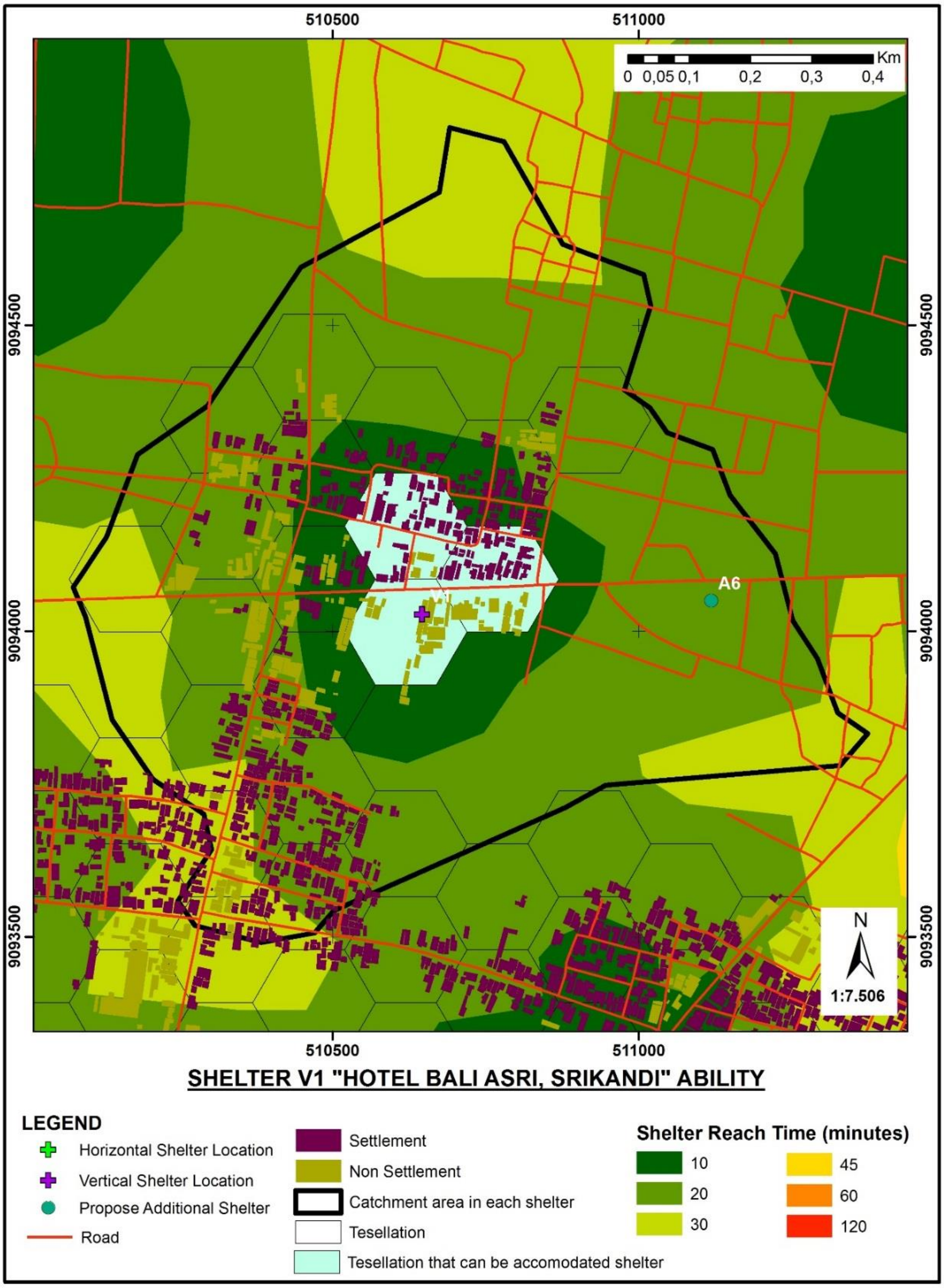
Appendix 27. Figure of Shelter H4 “Puncak Tamperan” Ability



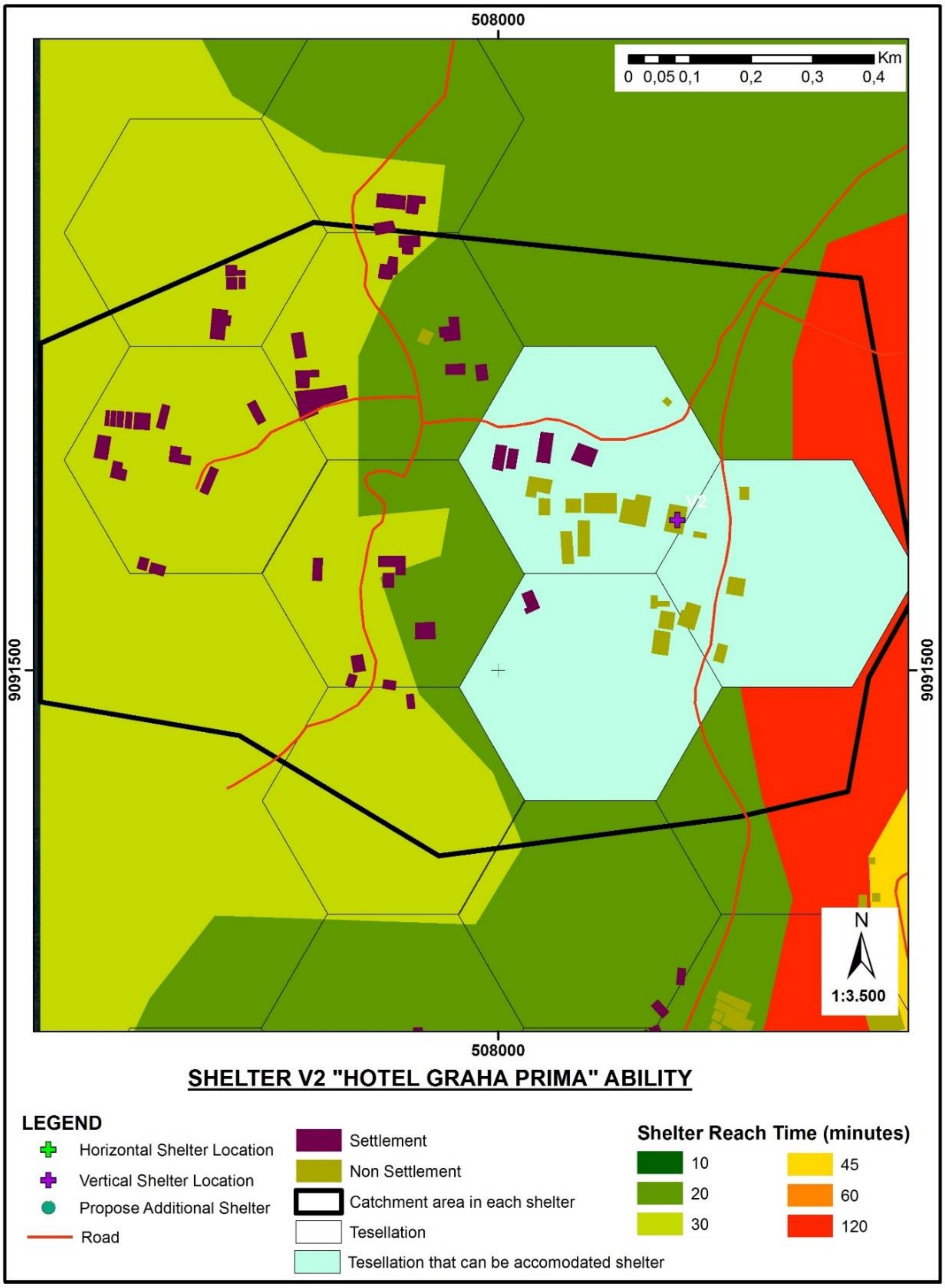
Appendix 28. Figure of Shelter H12 “Puncak Kandangsapi” Ability



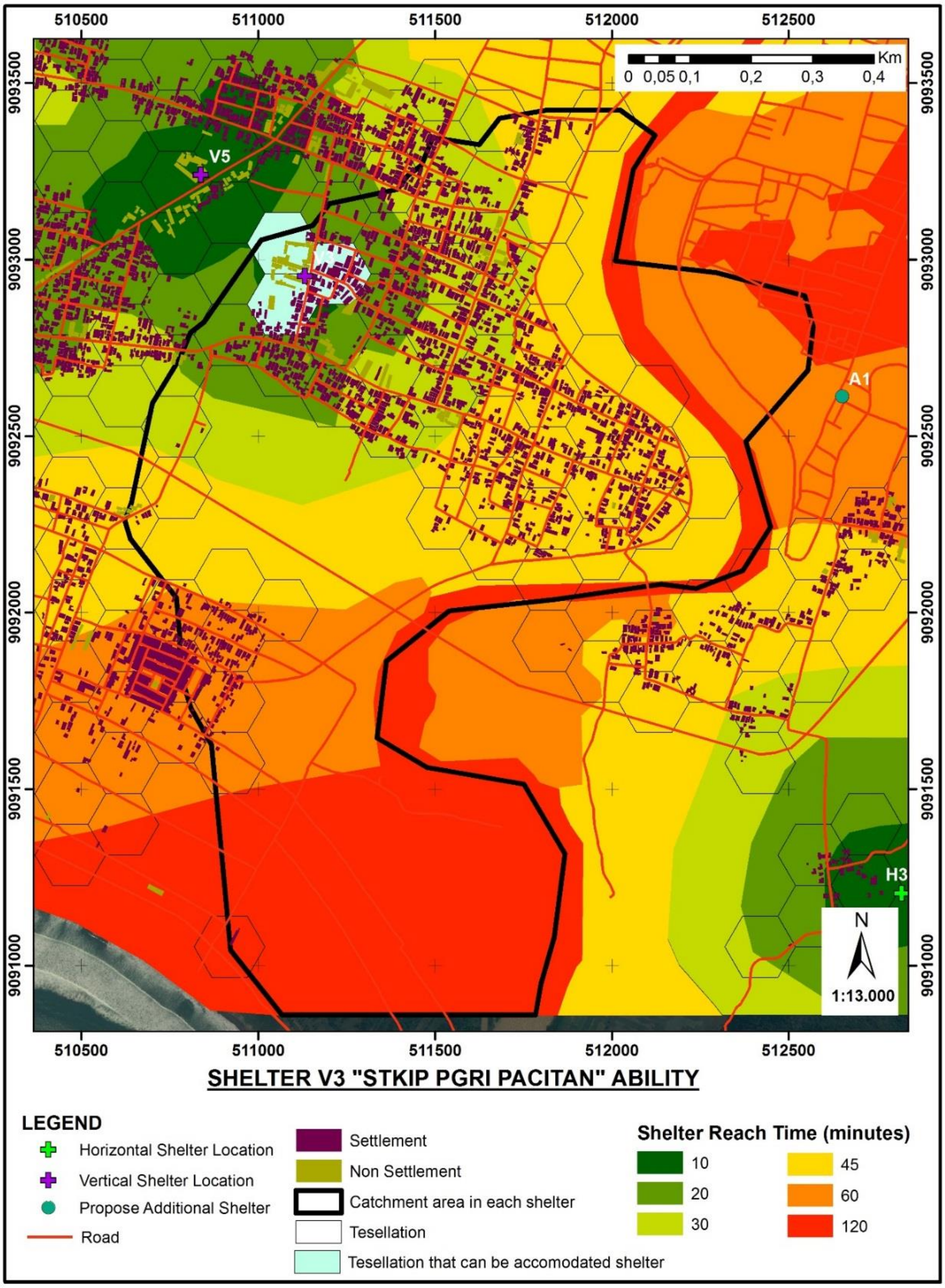
Appendix 29. Figure of Shelter V1 "Hotel Bali Asri and Srikandi" Ability



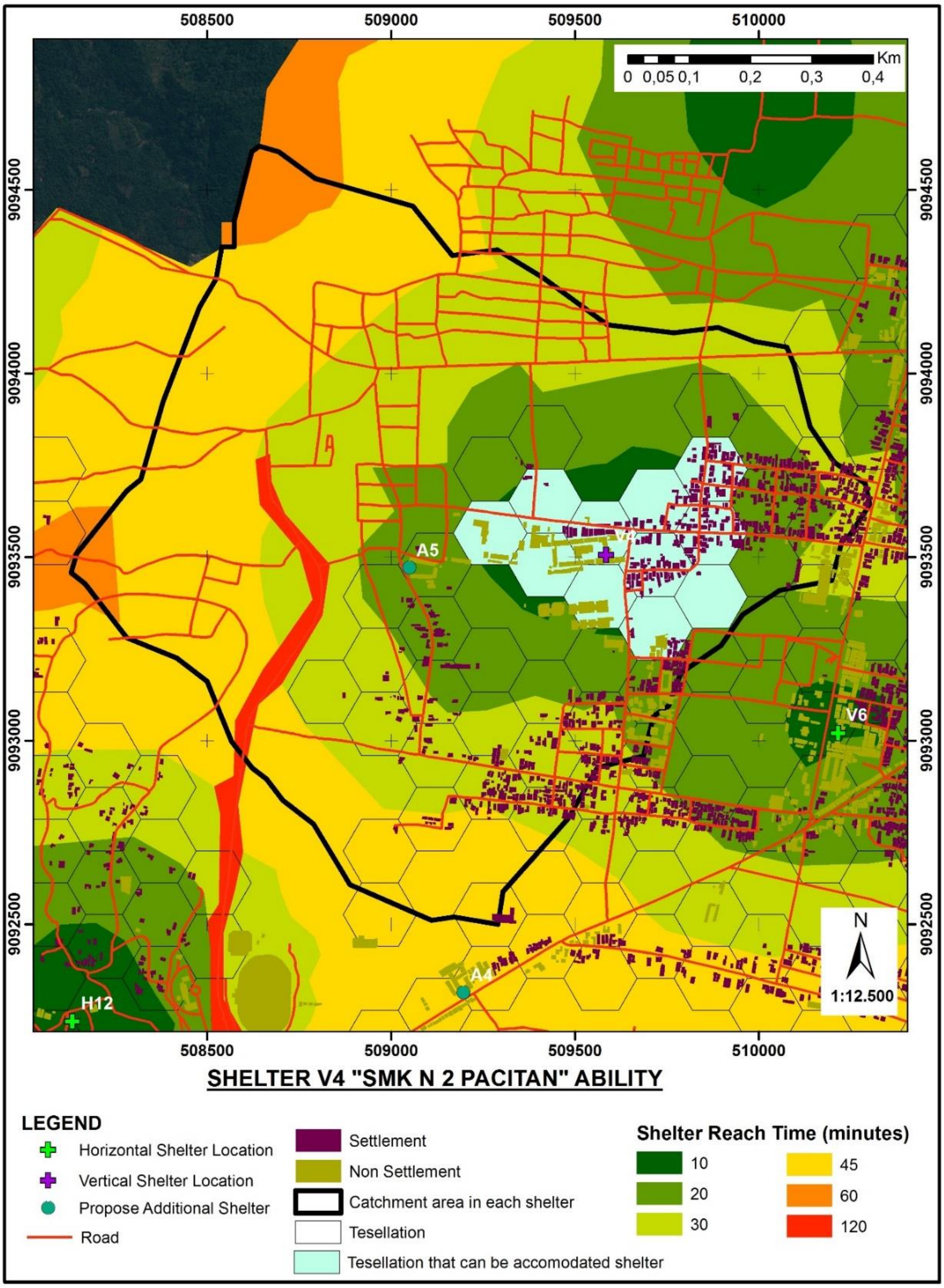
Appendix 30. Figure of Shelter V2 “Hotel Graha Prima” Ability



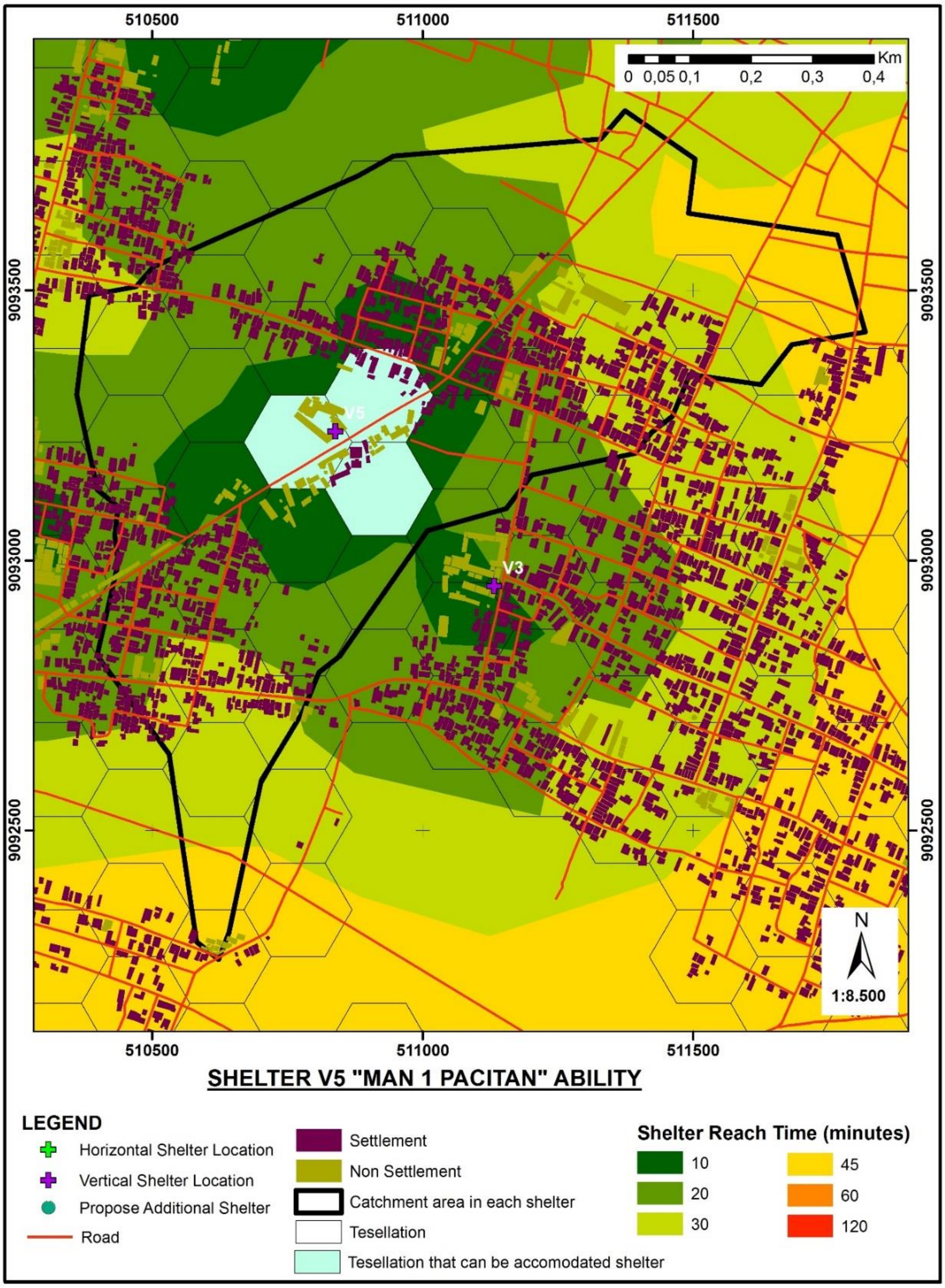
Appendix 31. Figure of Shelter V3 “STKIP Pacitan” Ability



Appendix 32. Figure of Shelter V4 “SMK N 2 Pacitan” Ability



Appendix 33. Figure of Shelter V5 “MAN 1 Pacitan” Ability



Appendix 34. Figure of Shelter V6 “SMA N 1, SMK N 1, SMK N 3 Pacitan” Ability