Tsunami evacuation decisions and behaviour: A case study of Pangandaran, Indonesia

R Wargadalam¹, H Nakanishi¹, Y Vidyattama¹, J Black², and Y Suenaga³

¹ University of Canberra, Australia
² University of New South Wales, Australia
³ Kagawa University, Japan

E-mail: rangga.wargadalam@canberra.edu.au

Abstract. The lack of an effective tsunami warning system is often blamed for the high number of deaths when tsunamis hit Indonesia. However, there are other factors affecting deaths: the scale of the incoming wave; a lack of community awareness of the problem; the lack of preparedness; or the ineffective communications prior and during the evacuation. This paper aims to explore the implicit knowledge of residents’ and to enhance the understanding of tsunami awareness and preparedness associated with tsunami evacuation behaviour in the village of Pangandaran, Indonesia. A field inspection survey and a residents’ questionnaire survey were undertaken. The results show that although there is a high awareness of tsunami hazards from past experiences, advanced evacuation planning is needed to enhance preparedness and reduce tsunami risks. Increasing trust in a tsunami warning, information dissemination, and evacuation drills are required to better manage the community’s evacuation. Uninformed shelter destination and route choice results in potential congestion on the main roads in the middle of the village and this slows evacuation thereby compromising survival rates. Appropriate shelter destinations and route choices need consideration and updating in the community. Promotion of greater resident participation in tsunami exercises is also recommended to raise awareness of the need for designated evacuation plans to be rigorously implemented.

1. Introduction
Indonesia is prone to earthquakes and tsunamis because of its geological location at the meeting points of tectonic plates. Since 1990, Indonesia has had more than 10 major tsunamis with casualties [1, 2]. The Indian Ocean Tsunami in 2004 caused 227,899 deaths and an economic loss of approximately US $10 billion [2]. The high number of 165,945 deaths in Indonesia from the 2004 Indian Ocean Tsunami [3] was attributed to the lack of a warning system that made it impossible for residents to know when they should start evacuating [4]. In the future, there is a strong probability of an even greater earthquake and tsunami happening again in Indonesia, especially along the Sunda Arc tectonic plate – a critical hazard to the southern part of the Java Island [5] that includes our case study area of Pangandaran.

Although there have been international advancements in early warning systems, a recent tsunami in Palu demonstrated that there is still a lack of an effective tsunami warning system in Indonesia [6]. Since the 2004 Indian Ocean Tsunami, the Government of Indonesia has tried to increase its capability to warn residents of potential incoming tsunamis and prepare them to be able to mitigate the potential disaster. The Indonesian Tsunami Early Warning System (InaTEWS) was developed in 2005 and officially launched in 2008 to warn not only people in Indonesia, but also people in the region around...
Indonesia [7]. However, the warning given is only an advice for local governments who have the political authority to call out an order for evacuation of its residents [7]. Therefore, the speed of information dissemination and warnings are dependent on local governments who have a central role in tsunami preparedness for residents.

The lack of an effective tsunami warning system is not the only reason for high death tolls in Indonesia from tsunamis. The lessons from Aceh, and other more recent events in Indonesia, suggest that a lack of peoples’ tsunami awareness, or knowing the dangers following a tsunami event, may also be a major cause of loss of life [8]. Also, without good communication tools to advise residents when, and how, to evacuate there will be delays in people leaving for shelters or higher ground. Therefore, to develop better policies in tsunami disaster mitigation and evacuation strategy in Indonesia, policy makers need to better understand how communities that face a high risk of tsunamis behave during emergency situations. This understanding will help policy makers to identify the vulnerable sections in the community and thereby recognise deficiencies in their current strategies.

This paper presents the results of a tsunami evacuation experience and knowledge survey undertaken in Pangandaran Village, Indonesia on March-April 2019. It discusses the implications of the respondents’ evacuation choices and behaviours on evacuation time required and on route congestion to shelters in an emergency tsunami evacuation situation. The paper is organised in the following way. Section 2 reviews the literature that this paper has used regarding tsunami evacuation and how people behave in evacuation situations. Section 3 presents the current situation of the case study area and characteristics of its residents. This section also explains how the research in the area was conducted through a field inspection of the village, a questionnaire survey of its residents, and interviews with residents and local officials. Section 4 presents the findings of the fieldwork, survey, and interviews in the case study area. The discussion and analysis of these findings are found in Section 5. Section 6 concludes this paper and identifies further work that will be undertaken in our broader research design.

2. Literature Review

2.1. Tsunami Mitigation

“Evacuation” is the effort to reduce loss of lives due to a hazard by moving people away to safety [9]. Tsunami evacuation could be horizontal evacuation by moving away from the shoreline or vertical evacuation by moving upwards in tall buildings or by climbing hills, towers, or trees. Hard measures to mitigate tsunamis, such as seawalls, may reduce impact, but evacuation (a soft measure) is an essential effort needed to save lives [8, 10]. Ando, Ishida, et al [11] found that there are factors that affect evacuation and evacuation choices such as inaccurate earthquake hazard assessment that affected government policy for tsunami mitigation (shelter capacity and public preparedness); inaccurate, or un-disseminated, tsunami warnings that may reduce preparedness of residents; past experience of smaller tsunamis that also affect preparedness, making residents assume the next tsunami will also be as small; and overly trusting hard measures. Evacuation preparedness will help save more lives, especially in areas where tsunamis can arrive very quickly - as in Indonesia. For example, the Smong culture on Simeulue Island teaches its inhabitants to run to the hills in case of earthquakes and this advice has saved more lives in contrast to the other areas in North Sumatra during the 2004 Indian Ocean Tsunami [12, 13].

In Indonesia, there have been various developments on tsunami mitigation infrastructure in high risk areas initiated by the national government. Two examples are: 1) an evacuation shelter built in Pangandaran and a tsunami museum in Aceh that can function as a tsunami shelter; and 2) building seawalls in high risk areas to mitigate destruction from tsunami behind the wall [14-17]. However, despite these examples of tsunami infrastructure, there is still no coordinated and concrete program that develops tsunami preparedness for residents [14]. Tsunami preparedness is especially needed in Indonesia as the hazards of an incoming tsunami can occur very quickly: the 2018 Palu and Donggala earthquake took only 6 minutes from the earthquake event until the tsunami arrived [18]. During that earthquake, some residents, whilst they felt the earthquake, did not leave the coastal areas because they did not hear tsunami warnings [6]. A volcanic tsunami in 2018 in the Sunda Strait killed around 437
people when most residents did not feel an earthquake and were not warned of the tsunami by officials [19]. There is still a lack of a warning system for tsunamis caused by volcanic eruptions and landslides.

2.2. Evacuation Behaviour
One of the complexities of evacuation is the inconsistent, and sometimes illogical, decisions made by evacuees, such as approaching beaches to sight an incoming tsunami [20]. Evacuation does not always start immediately, and it depends on the knowledge of each individual. People react from different triggers at different points of time to start their evacuation [21]. Trust of information and warnings also affect decisions to start evacuation or to seek more information before acting [22, 23]. What factors that might affect evacuee behaviour decisions can be conceptualised in ‘Figure 1’ [24].

![Figure 1: Factors of Evacuation Behaviour Based on The Protective Action Decision Model](Source: First author based on Lindell and Perry [24])

Using this model, we attempt to: identify the psychological process of potential evacuees after receiving a cue or warning of a risk; and to attempt to map out the stages of the individual’s thought processes in making decisions. In ‘Figure 1’ the first stage is the pre-decisional process where the individual tries to comprehend the threat. The second stage is how the individual perceives that threat and adjusts to not only the threat, but also to the environment and to other stakeholders involved. Finally, in the third stage, the individual makes a series of decisions on the actions that he or she will need to take to deal with the threat. The decision that these individual evacuees make is unique because it is based on experience, knowledge, physical capability, and social condition [24].

Other factors may affect the evacuation behaviour of different individual evacuees. Different triggers may determine when individuals will realise the upcoming threat and the need to evacuate. The triggers of tsunami evacuation start time can be the preceding earthquake itself, a tsunami warning, a reaction to seeing other people evacuating, or seeing the incoming tsunami itself [21]. Family circumstances and caring for friends may affect the decision as to whether to move directly to a safe location or to confirm the safety of family/friends first. For example, a high percentage of people who evacuated during the 2004 Indian Ocean Tsunami did not evacuate alone and choose to evacuate with family and friends [25]. Physical factors, such as age, socio-economic status and vehicle ownership, will affect how evacuees
will chose to evacuate (mode of transport), where they will try to go (shelter destination), and the route that they will take. A successful evacuation is often affected by the characteristics of evacuees (age, family members, gender, experience), as well as whether the community have received training and early warnings for the hazard of tsunami [26].

Identification of where residents will choose to evacuate to, what routes they will take, and what mode of transport they will use are important details for disaster management stakeholders as we have identified in the case of Indonesia. Not all regions in Indonesia have planned designated shelters where evacuees can get to [27]. Some communities behave differently, having their own strategies for evacuation rather than conforming to what the Indonesian Government has planned [14]. Uneven allocation of shelters, congestion of certain routes, and isolated individuals during a tsunami emergency are some of the challenges that policy makers in Indonesia must consider. Understanding the weaknesses of current tsunami evacuation strategies will help plan better development of evacuation plans for those areas lacking in tsunami evacuation infrastructures.

3. Methodology
3.1. Study Area
The study area, Pangandaran Village, has a population of around 11,000 people, and is located in the southern coast of West Java Province (‘Figure 3’). The Indonesian administrative level of local government is divided into levels of Province (Propinsi), Regency (or District)/City (Kabupaten/Kota), Sub-district (Kecamatan), and Villages (Desa/Kelurahan). The village lies in the regency and sub-district of the same name (in this instance, Kabupaten Pangandaran, Kecamatan Pangandaran, and Desa Pangandaran). In 2006, a 7.7 magnitude earthquake caused a tsunami [28] that killed more than 800 people and caused significant damage to infrastructure in the area [2]. It is one of the highest disaster-prepared areas in the region [29]. After that tsunami, there has been more effort by the local government to raise disaster preparedness through dissemination and warning system infrastructure implementation and improvements. Efforts to increase preparedness through community involvement have been regularly organised by the local government. However, the participation of residents is still low, and this has been identified as a major challenge [30].

| Population [35] | 10,961 people |
|-----------------|--------------|
| Number of households [35] | 3,773 households |
| Occupation [35, 37] | | |
| Trade | 18% |
| Services | 34% |
| Tourism | 11% |
| Agriculture | 5% |
| Fishery | 31% |
| Others | 1% |

Figure 2. Demographic of Pangandaran Village

The key economic livelihoods of Pangandaran residents are tourism and fisheries. As a prominent tourist area, it is known for its surfing and various other tourist attractions. The fishing sector plays a significant part of the local economy [31]. Working hours in Pangandaran depend on the occupation, where fishermen mostly fish at night [32] and return in the morning to deliver their catch to fish auctions. Traders will open shops during regular working hours, especially at the weekends to facilitate the needs of tourists. Most of the peak times of residents (excluding tourists) at the beaches are in the mornings where traders open stores and fishermen return from their fishing trips. Therefore, the specific
conditions of any evacuation scenario will differ depending on the time of day and where the residents are currently located at that time of day.

Although the use of the internet is relatively high in Indonesia, communications are made predominantly through the mobile phone usage. Phones are generally used for entertainment purposes (social media, messaging), rather than information gathering [33] or browsing for news. At the time of our fieldwork, a small earthquake (less than 5 magnitude on the Richter Scale) occurred, and many residents contacted a disaster response volunteer to ask of a potential tsunami threat rather than looking up the information themselves (which is how the disaster response volunteer helping our research project realised that there was no potential tsunami warning).

![Figure 3: Map of Pangandaran, Island of Java, Indonesia](Source: ESRI. [34])

3.2. Questionnaire Survey and Interviews
In Indonesia, approval and support to undertake research in the area was sought both from the local government (Pangandaran Regency and Pangandaran Village) and from the local disaster management agency (BPBD Pangandaran). The survey team was then introduced by BPBD Pangandaran to a local volunteer in Pangandaran Village who is widely known to residents and who assisted in our research dealings with the community. Fieldwork was conducted during March-April 2019.

An inspection viewed the village environment and road conditions in Pangandaran Village, the location of shelters available for residents, and the location of the tsunami sirens. Potential evacuation routes were examined, with an inventory of the roads being recorded (widths and capacity of roads, availability of evacuation signs). The condition of tsunami sirens was confirmed from interviews with the local disaster management agency followed by a field inspection of some of the sirens in the area.
This provided us with an understanding of the base-case infrastructure when an emergency evacuation order be issued in the future by the local authorities.

To gain information on how the residents of Pangandaran behave during a tsunami evacuation, a questionnaire survey was distributed in the village. The sample population are residents who are 17 years or older living or working in Pangandaran Village. The questionnaire survey has a paper-based format. Participants were asked to answer questions on their experience and knowledge of tsunamis, and future choices they may make in an evacuation situation. The survey consists of 28 questions. The first sub-section of the survey asks about the experience of the respondents with disasters, in general, and tsunamis, in particular. Sub-sections 2 and 3 probe participants’ knowledge of tsunami evacuations and ask how participants might act in future tsunami evacuations. The fourth sub-section asks the route and mode of travel they might choose in future evacuation situations. Other questions are about personal information of the respondents: demographics such as age; gender; occupation; household numbers; and the length of time living in Pangandaran.

The survey was also administered through individual face-to-face meetings and through group meetings to gather as many respondents as possible (see ‘Figure 4’). The participants were approached during the daytime at the beach, outside shops, in markets, at fish auctions, and also by house-to-house calls. A workshop, sponsored by the Pangandaran Village Authority, was also conducted to solicit more respondents. This also raised the awareness of tsunami risks and the importance of having an evacuation plan. Residents were given the opportunity to ask for clarifications of some questions if they needed, which increased the number of valid responses. There was a very high completion rate of the questionnaire, and, in total, 183 responses were collected.

Figure 4: Collecting Responses Through Face-to-Face Meetings and at a Workshop, Pangandaran Village, Indonesia
(Source: Photos taken by the first author and a local volunteer)

Two types of qualitative interviews were conducted for this research. The first method was through a semi-structured interview with local disaster management officials to gain insights into tsunami mitigation and resident preparedness that has been facilitated by the both local and national government. Secondly, semi-structured interviews of residents who participated in the questionnaire survey were undertaken to ask them about their tsunami experience and to solicit reasons for their possible future behaviours at a time of a disaster. The second method of interviews involved discussions with and between participants during and after filling out the questionnaire survey. Some of the participants shared their experience after completing the questionnaire survey. These discussions occurred in an informal and spontaneous way. This rich information was especially useful in the interpretation of the survey results.

3.3. Condition of Pangandaran Village

The research team surveyed Pangandaran Village to determine the options for evacuation destinations for residents when there is a tsunami warning. One of the widest known of all shelters is the Pangandaran Grand Mosque, where, as a community facility, it has a parking lot and communal bathrooms. Another temporary shelter (the Civil Ministry’s Temporary Evacuation Shelter) is located beside a market and was built following the 2006 tsunami. A more permanent shelter is located outside
of the hazard zone - further inland in the hilly neighbourhood of Purbahayu Village. This area has a school and an adjacent field that can shelter many people. A nature reserve in the southern part of the Pangandaran peninsula also has a hill that can be used as a temporary shelter for nearby residents. Undesignated shelters, such as high-rise buildings (at least 20 m tall) around the beaches, may also be used as conveniently located temporary shelters for residents in the area. However, these latter places are appropriate for a stay of not more than a few hours.

Figure 5: Evacuation Shelter Choices (from top-left clockwise: Grand Mosque; Civil Works Ministry Temporary Evacuation Shelter; Purbahayu Village School and Village Office; Medium-rise Buildings; Hill in a Nature Reserve) 
(Source: Photos taken by the first and second authors)

The streets in Pangandaran Village (‘Figure 6’) are not very wide, where the largest roads are 8-metre wide 2-lane streets. Many of the roads in the village, especially around the local housing areas, are narrow, 2.5-metre streets. Therefore, the free flow of vehicles in the area is restricted. Although clear evacuation signs are posted (‘Figure 7’), not every intersection has signage. Therefore, it might be difficult for those evacuees not familiar with the area (such as tourists) to find their way to the shelters.

Figure 6: Streets in Pangandaran (From Left to Right: Wide Coastal Side Road; Narrow Street; One-lane Dirt Roads) 
(Source: Photos taken by the first author)
Within Pangandaran Village, according to the local disaster management agency (BPBD Pangandaran), there is only one available tsunami siren that is functioning in the village and only two (built by the National Meteorological Agency (BMKG)) out of 14 tsunami sirens that is functioning in the Regency. The Head of BPBD Pangandaran suggests that, ideally, there should be 30 units of tsunami sirens available for the 91 km of shoreline in his Regency. Furthermore, during a scheduled testing of the tsunami siren (10.00 am on 26 March 2019) the siren was not tested so its function was unable to be confirmed. Other sirens inspected that were not functioning had either their tower fallen to the ground or they did not have a functioning radio transceiver and were not repaired.
4. Survey Results

4.1. Questionnaire Survey and Interviews

With a population of Pangandaran Village as 10,961 (Domestic Ministry database as of 2019 [35]) the 183 responses represent a sample of around 1.7% of the total population. Regarding the age of participants, the older age population (>60 years old) within the Pangandaran Regency is around 11.6% [36]. Among residents who participated within the questionnaire survey, 6.1% are of the age 60, or more, so this age cohort is underestimated by almost one half. The percentage of children was not compared as no participant under the age of 17 years was recruited. In term of occupation, the highest percentages in Pangandaran Village are Fishermen (30.9%), Traders (28.8%) and Services (20.0%) [37]. The highest percentages of participants’ occupation in our questionnaire survey were Traders (40.7%), Fishermen (21.5%), and Services (14.1%). Whilst our survey respondents do not match exactly the Pangandaran population profile based on their age and occupation distribution, we believe that we have collected adequate information to better understand community responses on evacuation behaviour, especially so as fishermen participated in our workshops and interviews.

4.1.1. Residents’ awareness. Most of the respondents have experienced disasters in the past (86.1%, n=173) as shown in ‘Figure 9’ (some of the respondents did not answer all of the questions or responded incorrectly/provided more than one answer and the analysis of the data omits invalid answers) and have had to evacuate from a tsunami warning (86.9%, n=176). Most of them also know that there are evacuation drills that have been conducted in the village (78.6%, n=178) as shown in ‘Figure 10’. However, only around half of the respondents have participated at least once in these exercises (54.8%, n=175) and only around 10% of our sample regularly participate in evacuation drills (‘Figure 11’). Information gathered from an interview with a local government disaster management official suggests that participation by residents in the exercises proposed by the local government disaster management agency is difficult without there being some kind of compensation for residents’ time.

![Figure 9: Experience in Disaster and Evacuation in Pangandaran](image)
4.1.2. Attitudes to tsunami warnings. The most important tsunami warning for participants is either a warning from the government (through a tsunami siren or national meteorological agency/disaster management agency website) or a warning from a neighbour or friend (‘Figure 12’). Although participants think that tsunami sirens should be one of the most reliable tsunami warnings, many participants do not trust them completely and therefore will still spend time checking the reliability of this information by: looking it up at the internet (29.5%, n=166); by going to the coast to watch for any signs of an approaching tsunami (28.3%); or by asking local authorities (21.0%) or peers (16.2%) as in ‘Figure 13’. In addition, although tsunami sirens are available in the village and surrounding areas, the number of sirens that are not functioning, and the lack of testing and exercises influence how much they are trusted. During discussions with participants, it became apparent that they do have a little confidence with the tsunami sirens, but they are not entirely convinced whether they function correctly. Furthermore, if they receive a tsunami warning without feeling an earthquake, most will try to find more information before evacuating (76.1%, n=176). In the case of an earthquake where there is no tsunami warning, many respondents feel that they will only evacuate immediately if the earthquake was “somewhat big” (if there are cracks on walls and some buildings have fallen) (54.3%, n=173). About 30% of participants responded that they would not evacuate immediately, or not at all.
4.1.3. Evacuation preparation and starting point. Although 30% of participants said that they could evacuate immediately (30.5%, n=177), most felt that they needed time to prepare before they could start their evacuation. Approximately 25% think that they would need to spend more than 20 minutes before evacuating (‘Figure 16’). This length of time for preparation can be related to concerns for the need to prepare not only themselves but also for others, where most participants have family members or neighbours who need assistance in evacuating (young children, elderly, or disabled) (83.2%, n=179). This length of preparation is also linked to participants trying to bring things with them. Only a small number (25 respondents) answered that they would not try to bring anything with them in an evacuation situation (‘Figure 15’). Another concern of participants is if they are not at home during a tsunami warning then more than half (51.4%, n=181) will try to go home first before starting to travel to safety. This also ties in with concern for family and neighbours who need assistance.

An important finding is that respondents will try to find their families first: nearly 40% responded that they would not evacuate until they know the whereabouts of members of their family (38.2%, n=170). They will spend time to find them (‘Figure 14’). Only a small number of respondents say they will not try to find their family (12.9%) before starting to evacuate. During discussions between some of the participants and the first author (after participants had filled out the survey form) on how they could find information on the whereabouts of their family, the response was “using mobile phones”. After contacting their family, and confirming their whereabouts, they will not try to meet but all will evacuate to an agreed shelter rendezvous.
4.1.4. Evacuation destination and mode of travel. As shown in ‘Figure 17’, the most preferred evacuation destination of respondents is either to go to the nearest tsunami shelter (45.0%, n=151) or to the nearest high hill (33.1%). The majority of respondents will try to take their motorcycle as their travel mode (77.3%, n=172) and only a small proportion will not try to use any vehicle to evacuate (14.0%) ‘Figure 18’. Almost all of the respondents confirm that they know how to get to the shelter destination because it is a route they routinely take (65.0%, n=177), or, at least they know the general direction that they must take (32.8%). Although most of the respondents think that they know the route they will take, their estimations of travel times are quite varied as shown in ‘Figure 19’.
Figure 13: Preferred Evacuation Destination in Pangandaran

Figure 14: Evacuation Mode of Travel in Pangandaran

Figure 15: Estimation of Travel Time to Reach a Shelter in Pangandaran

4.1.5. Evacuation route. Respondents were asked to draw a probable evacuation route on a base map. There were 121 responses given by participants that showed their preferred route in case of an incoming tsunami from where they usually spend their time in the village. Whilst most respondents use a direct route to their preferred shelter, some also drew a route either first to their homes or first to get away from the shoreline, then to their shelter destination. A rendering was then done by using GIS [38, 39] depicting the number of times each street coincides with different respondents’ routes (‘Figure 20’). Most of the respondents chose the direction to the Pangandaran Grand Mosque as their destination. Other shelter destinations chosen are the Civil Works Ministry’s Temporary Evacuation Shelter (TES) that is located more in the village centre, and the hills in the nature reserve in the southern part of the peninsula.
It should be noted that the choice of the Grand Mosque as a destination is inconsistent with the answers given to the survey questions in section 4.2.3, where the TES is a closer shelter choice. When designing the survey, it was considered that residents would know available shelters in their village and know which is closest. However, unexpectedly, some participants chose the nearest shelter and drew a route to the mosque that was further away. This suggests that many participants may not know of the nearer shelter or there is another underlying reason for choosing other shelters.

5. Discussion
5.1. Preparedness and Evacuation Decisions
In facing any tsunami, implicit knowledge and cultures of residents may save more lives than any high-technological tsunami warning system or hard infrastructure [13, 40]. One of the concerns in evacuation management planning is the amount of time some respondents spend before they start evacuating. This is called “milling time” in the literature and 24% of the survey participants responded that they would need more than 20 minutes to prepare for an evacuation (‘Figure 16’). The National Disaster Management Agency (BNPB) recommends that the time available for evacuation after an earthquake and before a tsunami comes is 20 minutes [41]. This delay in the evacuation start is a serious concern as the evacuation starting time is one of the clear differences between the probability of surviving a tsunami and the probability of becoming a fatality [26]. Greater preparedness is needed in the study area to reduce this milling time.

Lack of preparedness, lack of communication around tsunami warnings, and lack of learning from past experience (similar to conditions of the 2011 North East Japan Tsunami) will compromise evacuation decisions when a bigger tsunami hazard threatens the study area [11]. Whereas contact through mobile phones is enough for some of the residents to confirm family member’s safety and then confirm the evacuation, if there are disruptions to communication networks panic will impede decisions
on evacuations. Dissemination of evacuation strategies to residents by the government, such as preparing emergency evacuation kits and discussing emergency plans and contacts with family members (where an imperative must be to adhere to an agreed individual plan of evacuation), will help reduce the possibility of confusion and delay in starting evacuation.

The lack of trust in the tsunami warning system also adds to delays in starting evacuation because participants try to gather additional information before making decisions (‘Figure 13’). Tsunami sirens that are not functioning are a problem (section 4.2.2). Other tsunami warnings through government websites (InaTEWS, BMKG, BNPB) are not commonly used as there is lack of inclination of residents to use the internet for information gathering [33]. Scheduled and informed testing of tsunami sirens and education of tsunami warning system information gathering for residents will raise the trust in tsunami warnings and help residents make faster evacuation decisions. There is also a need to reduce milling time by providing an all-in-one information platform where residents can get necessary information from one source rather than needing to do netsurfing.

Another concern revealed in our study is participation in tsunami preparedness exercise/training. Past events have given residents an awareness of the hazards of tsunamis. As mentioned in sub-section 4.2.1, 87% of the respondents have experienced the need to evacuate from a tsunami. However, despite the fact that most of the respondents know that tsunami evacuation exercises are conducted in their village, only a small portion regularly attend, and almost half of the respondents have never participated in evacuation exercises at all. Although residents in other tsunami affected areas have a low participation rate in disaster training, a high percentage of those people still survive [26]. However, this may be due to the fact that unprepared residents had some other ways to know of the danger (e.g. through warnings, official orders, and the behaviour and warning of those around them) or felt the danger from the earthquake and checking the tsunami itself. Without help from warnings and orders from officials, which was the case in the recent Palu and Sunda Strait tsunamis or having more prepared residents to warn and show the unprepared how to behave, more casualties are likely to occur.

This apathy to participate in evacuation exercises could be previous experience with tsunami evacuations or warnings, coupled with confidence in their own knowledge of what to do. This is a problem because some of the survey responses indicate they do not have appropriate evacuation knowledge. Past experience of tsunami (specifically smaller ones) that gives them a sense of “knowing how big” the tsunami will be, and over-trusting tsunami mitigation infrastructure puts them at a higher risk of when a bigger tsunami happens [11]. Also, some of their preferred behaviours, such as checking tsunami signs on beaches or a misperception of the time available for evacuation preparation, results in higher risks during evacuation. When the local government management agency was asked on the difficulties for participation in tsunami mitigation activities, they stated that one of the main reasons for the lack of participation is that some residents feel that they will lose income by being away from work or family and this is not compensated by government.

5.2. Evacuation Travel Decisions
There are three tsunami shelters designated by the government in Pangandaran Village (‘Figure 5’): a temporary evacuation shelter besides a market in the middle of the village (TES); the Pangandaran Grand Mosque to the north of the village; and on the hills of a nature reserve in the southern part of the peninsula. A more permanent evacuation shelter that is available is in the Purbahayu Village to the north, where it is further inland and has a higher elevation. Other available shelters are buildings taller than 20 metres around the village (such as hotels).

The questionnaire survey result shows that 45% of the respondents will choose the nearest shelter available as their destination. However, when asked to draw their route choice, the respondents’ route was in the direction of the Grand Mosque that is farther away than the TES near the village centre, which is contrary to their answers of their evacuation destination choice (‘Figure 17’). The reason for this unexpected contradiction might be that participants do not know of the TES shelter and that it is a closer destination choice. Another reason might be that participants not only seek safety in their destination, but also the religious/spiritual comfort the mosque can provide during stressful conditions of evacuation.
A more practical reason might be how far away from the shoreline their destination is. Although the TES’s height offers safety for the evacuees, the shelter does not offer protection for their vehicles parked under a building that is susceptible to the incoming tsunami. As more than 80% of the respondents stated that they will likely bring a vehicle (motor bike, car, or bicycle) in an evacuation, the availability of safe parking in shelters is an important requirement.

The route choices of respondents also show that although most of the routes they chose are in the direction of the Grand Mosque, some of them will continue to travel northwest or northeast out of the village. This is because the mosque is still in the hazard zone and is only designed to be a temporary shelter. They travel either to the northwest to Purbahayu Village, which is further inland where respondents can feel safer, or to the northeast in the direction of the nearest city of Banjar where more amenities are available.

Consequently, there is a high potential for congestion in the middle road leading out of the village (shown by the “red roadways” in ‘Figure 20’) and especially on the roundabout in front of the Grand Mosque. The area around this roundabout has a peak-hour around lunch time where activities from the nearby village offices, primary school, lunch areas, and mosque are at their highest. Congestion from those activities will delay traffic in and out of the village. Although there is an alternative route on the west of the village centre, not many respondents chose routes in that direction. During discussions on preferences in choosing routes to shelters, residents’ decisions are based on getting away from the coast as soon as possible. Therefore, participants tend not to travel along roads parallel to the coast, even though they are alternative routes to a safe shelter.

Stakeholders must consider the capacity of the village transport infrastructure when formulating better evacuation management. Considering the congestion of major roads in an evacuation scenario the authorities need to decide whether it is better to augment the capacity of those roads or to advocate for alternative routes out of the village. Alternative routes might be the coastal roads from the west (if it is deemed that there is available time) or an emergency road in the vacant areas in the northern part of the village (north of the TES where there is a lack of buildings, can be seen in ‘Figure 20’). This new road would be expensive to build with complex land ownership issues to resolve before a route could be secured.

The capacity of a shelter is also an important consideration. The Grand Mosque is a popular evacuation destination, but it needs to have enough space for the people who will take refuge, to build a hygiene facility, to provide comfort and privacy, and parking spaces. Another strategy for better management is providing better facilities in the alternative temporary shelters (in the TES and Nature Reserve) so that residents feel more comfortable choosing those alternative shelters as their destination. Having some amenities and a supply cache in the nature reserve hills will provide a better shelter choice for the residents in the southern part of the village. This may result in an improved distribution of traffic towards each shelter. Providing safe parking for the TES may also encourage more residents to consider it as a preferred shelter.

The village does not have a detailed evacuation management plan. Policy makers can develop a plan to design where residents in a certain area will go to and which route they should take. Therefore, shelters can be more evenly distributed, and route alternatives can be designed to deliver the least amount of congestion. However, the challenge in implementing any evacuation plan is for residents to follow it in an emergency situation given they have their own particular behavioural preferences. Community workshops, collaborative planning and exercises must be conducted with the residents. Incentive to encourage more residents to participate is currently one of the challenges revealed from the questionnaire survey. Besides raising funds for compensation to be given to participants, more economic solutions may be available, such as having fisherman, for instance, conduct exercises in times/seasons not suitable for fishing (strong winds, unfavourable tides), whereas exercises for traders/guides may be held during weekdays when there are not many tourists coming to their area.

Informing residents of the consequences of lack of preparedness may also persuade more of them to attend exercises. Residents should be reminded that unpreparedness for tsunamis might not only result in loss of life, but it also will bring economic losses. Preparedness also plays an important role in
tourism, as well-prepared communities will raise trust in the tourists and lessen the anxiety of people that plan to travel to the region. These exercises may also be in conjunction with other programs undertaken by the government, such as part of capacity building exercises with segments of the program dedicated to disaster mitigation.

6. Conclusions and Future Work
The results of this study show that the evacuation decisions and behaviours in a tsunami scenario in Pangandaran Village are not informed by appropriate risk assessment, education and discussion. Although a high awareness of tsunamis is revealed, some “inappropriate” evacuation behaviours and preferences have been unearthed. Insufficient participation in tsunami exercises indicates that there is a lower preparedness for tsunami evacuation in this village. The lack of absolute trust in tsunami warnings, and the need to confirm an approaching tsunami by gathering additional information, can lead to indecisiveness that, in turn, adds unnecessary milling time to evacuate. Concern for family and efforts to search and confirm the location and safety of family members will further delay evacuation thereby putting evacuees at a higher risk of death and injury.

Considering respondents’ preferred evacuation destination and route choices, and also the extension of evacuation start time because of the concerns above, there is a high probability of congestion in the major road of the village. This will result in higher risks to the survival rate of the evacuees. Disaster management stakeholders must formulate better evacuation strategies and plans. This includes the consideration of alternative shelters and routes to those shelters. Greater availability of shelters will provide destination choices that will result in a more equal traffic distribution and less road congestion. Promoting and building alternative routes to the main shelters will reduce congestion and lower the risk for evacuees. These actions should result in a shorter mean evacuation time for the whole village. Finally, better promotion/education and strategies are needed to raise participation of residents in evacuation exercises so that residents gain a greater preparedness and understanding of behaviours they should follow during an evacuation.

Our overall research design is to use these behavioural responses by Pangandaran Village residents as input in the development of an agent-based evacuation model. More generally, such simulation models can help those in the Indonesian national, provincial and local governments to develop tsunami mitigation and evacuation strategies and better engage with local communities through the visualisation capabilities of such models. Tsunami and inundation scenarios will be specified. Using the model, simulation of alternative optimal routes and shelters can be conducted, which will demonstrate how to reduce evacuation delays. The model will help to understand in more detail the intersections and routes that have a high risk for congestion in an evacuation situation. The model is anticipated to be an additional tool for decision-makers to help determine evacuation route choices of residents and the problems that may arise from residents’ evacuation choices. Having an approximation of the time it takes to complete an evacuation will demonstrate the risks posed to residents. This will increase awareness, and both encourage residents to reconsider their family plan for evacuation and to attend drills and education opportunities.

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