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Assessment of Tsunami Mitigation Measures

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Abstract

Since the tsunami of December 26 2004 there has been considerable rebuilding, and procedures and infrastructure have been set up to help minimise the loss of life and property caused by such catastrophes. Actions have been taken by local community groups and by multi-national aid agencies which combined local community knowledge with the resources available to larger international groups. These measures include such actions as improved detection and early warning systems, improved, the building of refuge and planning escape routes. In this paper we review the various measures adopted in areas likely to be affected. Using Banda Aceh, one of the areas most affected, as a case study, we examine the extent to which these strategies have been realised in practice (in terms of reconstruction and rehabilitation), and evaluate the likely impact of the strategies to be applied.

Keywords

Disaster planning, tsunami, escape, early warning system

1. Introduction

Tsunamis are cataclysmic events that happen at irregular intervals. We can do nothing to stop them, but we can try to minimise their impact by planning for them. The main impact they have is loss of life and property. While they tend to happen without warning, the impact of a tsunami may be felt at a great distance several hours after the initial event causing the tsunami, so we can take appropriate action, but only if systems are in place to warn those affected, and the infrastructure to enable this action to take place exists. The largest tsunami in recent times was that which affected the Indian Ocean in December 2004, and this is used as a case study to demonstrate the kinds of warning system and infrastructure building that can be used, focussing on Banda Aceh, the area worst affected.

Apart from the loss of life there was considerable displacement of population, loss of property, and environmental impact. Of course there are many other issues related to the impact of a tsunami, such as providing immediate shelter, fresh water and food, and medical help, and also long-term planning for providing permanent homes for survivors, planning resilient new buildings etc. This paper, however, focuses on reducing the casualties by providing warning systems and immediate refuge from the tsunami.

Preparedness and response to tsunamis include a number of steps

- Identify areas at risk and raise awareness
- Install detection system
- Install warning system
- Devise response plan, e.g. escape routes

2. Identifying areas at risk

Clearly the first task is to identify areas at risk, which obviously include coastal areas in regions with a high earthquake risk. Within those areas there are gradations in the degree of risk, and it is useful to discriminate between areas where the risk is higher or lower, within a region. It is not only the height of the land and its proximity to the coast that determine the risk; tsunamis can penetrate significant distances, up to 10km, along coastal rivers and reach areas which people might perceive as safe. Sambah and Miura (2014) used GIS to develop a spatial multi-criteria method based on height, slope, proximity of rivers, and other features, to map vulnerable areas.

3. Tsunami awareness

Once a region has been identified as potentially at risk, one of the most important initial tasks is to alert the public to that risk. This can be done by education in schools, through television and radio, and local newspapers. Reinforcement of the message at regular intervals through disaster education workshops has been carried out in high schools, universities, public offices, open spaces and mosques in Banda Aceh (Sugimoto et al).

There are other ways of maintaining people's alertness which have been used in a number of places which have suffered from tsunamis, such as the erection of memorial statues and poles. Poles marking the high water marks from tsunamis act as a constant reminder of the risk, and promote better understanding of the geographical conditions in their cities. In Banda

Aceh city and Aceh Besar a total of 85 tsunami height memorial poles were erected in 2007 (Figure 1). The value of local knowledge and experience of a tsunami is inestimable, but in spite of the 2004 tsunami, questionnaires in 2006 showed that the local people's awareness of tsunami was very low (Sugimoto et al 2010). Activities such as practising escape drills etc. can also help to foster better community relationships between residents and the organisations involved (Wise).



Fig.1 Tsunami memorial statues located in banda aceh open space

4. Early warning systems

The Tsunami of December 2004 was triggered by an underwater earthquake occurring at 00:58:53 UTC with its epicentre at 3.316°N, 95.854°E, 160km off the north-west coast of Sumatra. It was the single worst tsunami in history, over 230,000 people in 14 countries dying as a result of it. The waves reached a height of 24-30m coming ashore in Aceh. Tsunami waves travel very quickly through open water, up to 800km/h in deep water. There were no tsunami warning systems in the Indian Ocean at the time. The time elapsing between the earthquake and the tsunami reaching the shore varied from as little as 15 minutes in northern Sumatra to 90 minutes in Sri Lanka and India, while Thailand was struck after about 2 hours. A 1.5m high tide even reached South Africa some 16 hours after the earthquake. In the absence of any kind of warning system, the people of northern Sumatra only knew of the approaching tsunami when the wave was visible from the shore, by which time it was too late for most people to take evasive action.

An early warning system for tsunamis comprises two major elements; a system for detecting a tsunami, and a means of communicating the information to those likely to be affected.

Seismic gauges can detect the occurrence of an earthquake which may cause a tsunami, but using this data alone will produce many false alarms, as only a small proportion of earthquakes results in a tsunami. Other detection methods, such as pressure recorders in the deep ocean and tide gauges to monitor coastal sea levels, have to be used in combination with them. Pressure recorders on the sea bed measure the weight of water above them, and a buoy above monitors the surface conditions. Although expensive to install and maintain, such systems have the advantage that they can detect a tsunami wave far out at sea and give advance warning.

In Thailand an early warning system has been set up by the National Disaster Warning Centre which includes 136 warning towers and three tsunami-detection buoys – one near the coast

and two others in deep sea. If an abnormally high tidal wave is detected, the buoys send data via satellite, which is then double-checked with data from the Thai Meteorological Department, the US geological survey and the World Meteorological Organisation. If the occurrence is confirmed, the centre calculates the wave direction and expected arrival time. Warning messages are then sent to the media and other agencies via fax machines, telephone hotlines and radio and television stations. The technology to send messages to 90 million mobile phones exists but budget constraints prevent this at present (The Nation, 2012). There is always a level of uncertainty surrounding such systems, since it is not possible to predict with any accuracy which seismic events will trigger a tsunami, and false alarms are inevitable. An Indian Ocean Tsunami Warning System was set up following a UN conference in 2005 in Japan.

5. Damage prevention systems

Physical barriers to prevent sea water from inundating areas that are usually dry such as dykes and breakwaters can protect areas from the tsunami. Significant costs may be incurred in creating such large earthworks, and, as experience from the 2011 Eastern Japan tsunami shows, they may not be totally effective; even so, they may at least delay the inundation, providing valuable extra time for evacuation to take place (Esteban et al, 2013).

6. Response/Escapes plans

Preparedness and creating appropriate response and escape plans is a matter for both national government and local communities. The community-based disaster-preparedness (CBDP) approach is being adopted worldwide and allows advantage to be taken of local knowledge, but places more responsibility on individuals to make themselves aware of what they have to do in an emergency. For example, people must be made aware that they cannot necessarily sit and wait for the police or army to help them, as access may not be possible. It also makes use of the experience of those who have been involved in a tsunami, and community leaders will work together with government and other agencies to devise escape routes and refuge areas (Said et al, 2011). Evacuation plans, including recognised escape routes to higher ground or refuges, will need to include the task of acquainting people with the escape route network and the location of refuges (Figure 7). Escape routes are likely to include existing roads and street networks, but widening or upgrading may be necessary to allow the rapid evacuation of large numbers of people.

7. Refuge systems

These include buildings to which people can escape and remain safe until the main tsunami event is over. They are made of reinforced concrete and include stairs and ramps, and are in the form of open-sided multi-storey buildings resembling multi-storey car parks. Helipads on the roof help with providing food supplies and rescuing the injured.

8. Case study – Banda Aceh

Banda Aceh, the capital city of Aceh province in Indonesia, was the city worst affected by the 2004 tsunami. The catastrophe killed around 61,000 people (Nurdin, 2006), which is about 30% of the total number of killed people in the disaster (Fachrurazi, 2012). Tsunamis are infrequent events but can be extremely destructive (National Tsunami Hazard Mitigation Program, 2001), and the total estimate of damage and losses from this catastrophe for Indonesia alone was US\$4.45 billion (Rp41.4 trillion), (Masyrafah et.al, 2008). It is therefore essential to prepare for evacuation and emergency response against any future tsunami. In seven Principles for Planning and Designing for tsunami Hazards released by the National Tsunami Hazard Mitigation Program (2001), identifying areas at risk is the first principle.

In the case of Aceh, Fachrurazi (2012) showed that the deaths caused by the 2004 tsunami in Banda Aceh, were not evenly distributed within the affected area in the city. The number of casualties depended on the location of casualties, density, condition of the environment, distribution of wave force, etc. The map of the mortality rates in each village in Banda Aceh (figure 2.a) is very informative in specifying the areas at most risk from a tsunami.

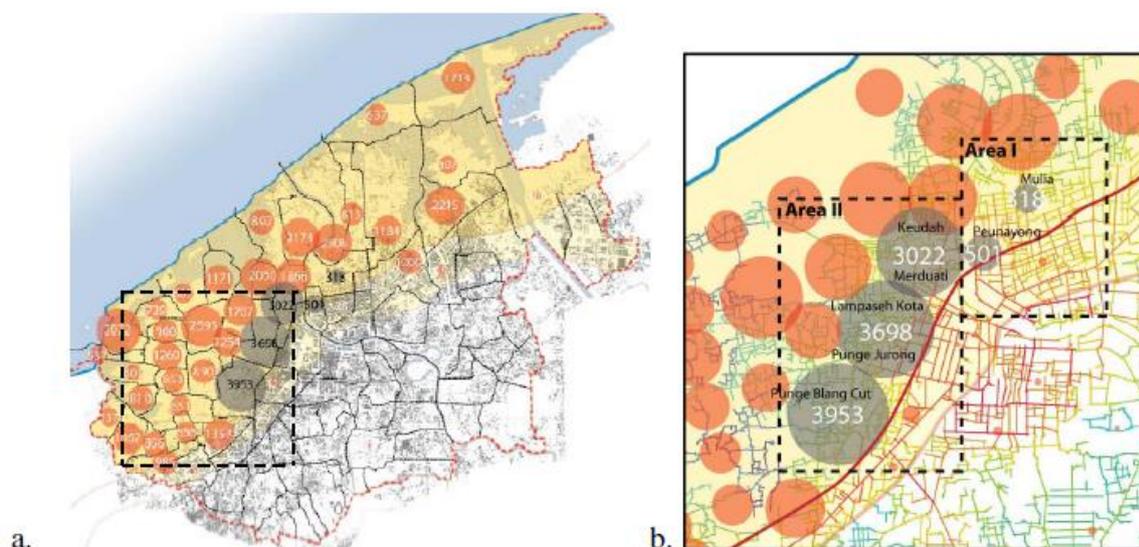


Figure 2. The Map of the mortality rates in each village in Banda Aceh (Fachrurazi, 2012)

The grey circle in Figure 2.a which is shown in detail in figure 2.b indicates the high rate of mortality occurring in Punge Blang Cut, Punge Jurong, Lampaseh Kota, Merduati, and Keudah. The villages are not actually near to the coast, yet appear to have suffered a high number of victims. Figure 2b, where the mortality rate map is traced on the street and road network of Banda Aceh, shows that those neighbourhoods with most casualties consist of a labyrinthine street network with several dead end streets.

Seemingly, many people did not manage to escape to the main north-south route through the whole city, and it seems likely that many of them became trapped in dead end streets or got lost in the labyrinth of streets. This explains that the more spatially segregated the street network is in a local area, the higher mortality rates (Fachrurazi, 2012). Figure 2 also shows that the inundated area reached up to the city centre, where the population is high and it is a more crowded environment. It thus becomes a major challenge to plan the city well to prepare for any disaster.

Understanding the community's tsunami hazard, vulnerability, and exposure to damage is the foundation for land use and building strategies that can mitigate tsunami risk. Following the tsunami, the Acehese government therefore zoned the land use in Banda Aceh, as shown in figure 3. Banda Aceh was divided into four zones which are developed based on DRR (Disaster Risk Reduction) principles, namely: coastal zone, green zone, limited development zone and new development zone.

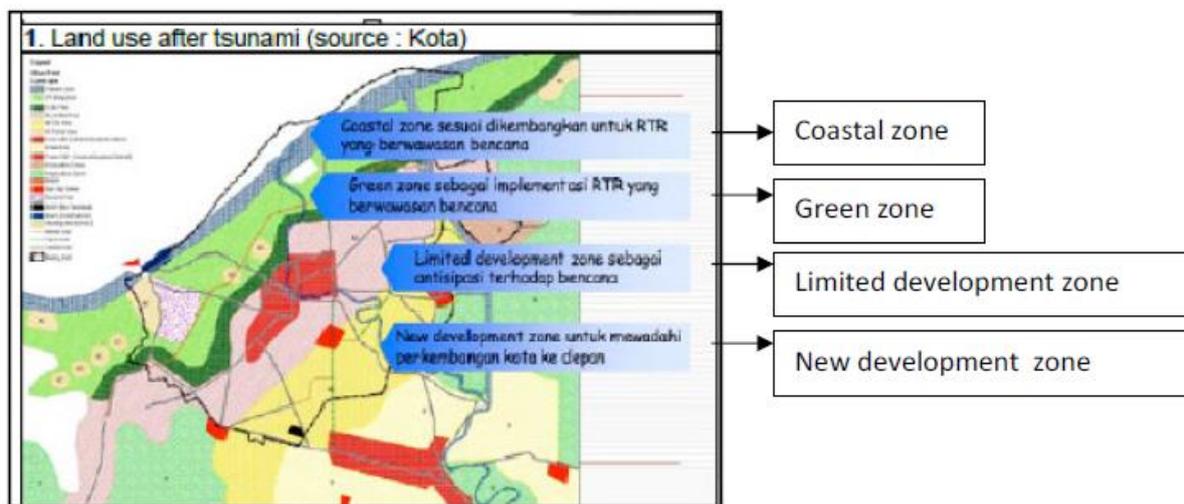


Figure 3. Land use of Banda Aceh after tsunami

The area within 2 km of the shoreline is named Buffer Zone and restricted for housing. The Coastal Zone is seen currently as the water front recreation area which was developed to be part of tsunami heritage. Some parts of the coast close to downtown have been protected with berm along the coast. In addition to reducing the speed and the height of tides it also provides a safer area for people enjoying the beach (Figure 4).



Figure 4 Coastal Zone

However, several post houses are still located along the coast (figure 5), whilst the green zone is mostly populated with houses.

A neighbourhood called Lambung in the green zone was swept away and lost 90% of its population during the tsunami. After the tsunami, Lambung was redeveloped and re-occupied (figure 6).



Figure 5 Housing built along the coast.

This happened because the opinions of residents who wished to stay in the same village were respected by BRR (Agency for the Rehabilitation and Reconstruction of the Regions and Community of Nanggroe Aceh Darussalam and the Nias Islands of the Province of North Sumatra); based on such community agreements, approval was granted to rebuild residences in coastal areas. As a result, many houses were rebuilt in the zones designated as restricted areas, that is, in coastal areas that had been flooded by the 2004 tsunami. However, Matsimaru made a foot note that although it was said that this was done in agreement with the wishes of the community, through interviews it was discovered that this was not necessarily the case. Most people had to return to the place where they originally lived because they had no other choice (Matsimaru, 2012).



Figure 6. Lambung Village in the green zone, after the tsunami and after reconstruction.

Given the presence of post-tsunami housing near the restricted area, providing some means to escape from a tsunami is the only way to save residents' lives. Therefore JICA proposed escape route networks (figure 7).



Figure 7 Escape route network as proposed in the master plan (JICA, 2005).

Another important tool to rescue people during the tsunami is the presence of escape buildings. Currently there are four escape buildings in Banda Aceh located in the following villages, i.e. Deah Teungoh, Deah Glumpang, Lambung and Pie (AtjehLink, 2014). The buildings can accommodate 800-1000 refugees, but this number is actually still not enough to save all the people (Kompas, 2012). However when the city was shaken by another earthquake in 2012, most of the civilians did not escape to the buildings. Only about 50 people escaped to each escape building, while most other people escaped by riding motorcycles to higher areas, creating chaos on the main road (Kompas, Jumat 13 April 2012). That this happened may be due to the absence of knowledge about the function of the escape buildings among the people.



Figure 8. Escape building in Banda Aceh

The distribution of tsunami mitigation knowledge among the people as the users of the tsunami mitigation facilities is very important. If not, the facilities will be useless and money will be wasted. Tsunami memorials are another way to remind people about the tsunami. Although people keep disaster experience and awareness just after the disaster, over time they gradually lose their memory of the disaster, lessons and awareness as time passes. Therefore it is important to build social systems to maintain disaster awareness and transfer the lessons to the next generation. Tsunami statues or tsunami memorial poles prevent disaster memory wearing thin with time. Tsunami height poles visualize the disaster for the next generation. Without such devices as poles or statues, people are likely to forget lessons from disasters (Sugimoto, et al, 2014). In Banda Aceh, the tsunami memorials are built either in the form of statues or as religious reminders such as mosque and mass grave. For Muslims in Aceh, tsunami happened as the warning of God to remind Acehnese people to become closer to their God. Many Muslims from other places come visiting Aceh planning their time to do prayers in the surviving mosques and visiting the mass grave of the tsunami victims.



Figure 9. Tsunami memorial statues built in villages affect by tsunami.

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