New Tsunami Disaster Mitigation System considering Local Conditions of Indian Ocean Rim Regions

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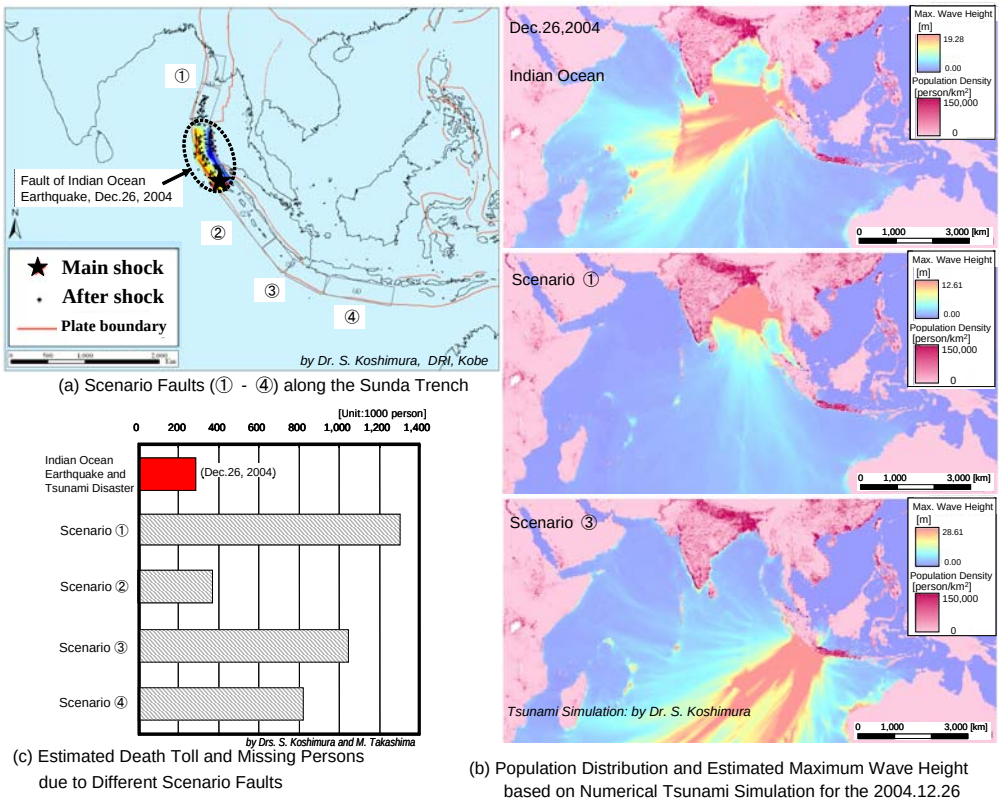
SUMMARY
This paper introduces the New Tsunami Disaster Mitigation System, considering local conditions of Indian Ocean Rim regions. The newly proposed system is composed of a reliable tsunami warning system and proper evacuation facilities. The warning system consists of multi-purpose observation buoys operated by local organizations such as hotels and beach associations. The system is not only used for tsunami warning but also to monitor information like temperature, current velocity, wave height, moisture, etc., which can be used on a daily basis for the economic and business activities of the region. In order to verify the suitability of the proposed system, tsunami and evacuation simulations are carried out. The strong points of the proposed system are its simplicity, economical affordability and daily usability, which makes it a sustainable option for the region.

Keywords: New Tsunami Disaster Mitigation System, multi-purpose observation buoys, Indian Ocean

1. INTRODUCTION

Triggered by the M9.0 Earthquake that occurred along the Sunda Trench, Off-Sumatra, at 07:58 (local time), on December 26, 2004, a huge and devastating tsunami hit the Indian Ocean Rim countries, causing unprecedented disaster with over 230,000 dead and missing persons (JSCE, 2005, Meguro, 2005). The tsunami was triggered by one of the possible earthquake scenarios along the Sunda Trench. Four other potential earthquake events along the trench have been identified and the expected number of casualties in case they occur has been estimated. As a result, it was revealed that 1.3 million dead and missing people are expected, at worst, as shown in **Figure 1**. This number is several times larger than the observed in the December 26, 2004 event (Takashima, M. et al., 2005), and shows that an effective and sustainable framework against tsunami disaster is indispensable in this region.
Some countries along the Indian Ocean rim have established a tsunami disaster mitigation system based on land use, i.e. prohibiting people inhabiting next to the seaside. Others are planning to adopt similar measures. Land use control is an efficient measure if people follow it. However, this is not always a proper option in case activities such as fishing and tourism, which are the pillars of the region economy, take place directly next to the shore. Under these conditions, it is inapplicable to implement land use control policies.
In the Pacific Ocean Rim region, tsunami disaster mitigation relies on a sophisticated warning system, which is used not only for disaster mitigation but also for earth science research. This system is costly in terms of both installation and maintenance. Furthermore, it requires a great deal of knowledge to operate it. Although it is very useful and appropriate for this area, where countries with financial and technological resources are located, it is not applicable for the Indian Ocean region (**Figure 2**).
Taking the above mentioned points into consideration, a New Tsunami Disaster Mitigation System which combines a tsunami warning system suitable for the Indian Ocean region and proper evacuation facilities in terms of location, strength and sheltering capacity is proposed. With this system, there is

no need to relocate the people living along the seashore; therefore, there is no impact on the local economies. The proposed system is simple, economically efficient and daily-usable.



(a) Scenario Faults (① - ④) along the Sunda Trench

(c) Estimated Death Toll and Missing Persons due to Different Scenario Faults

(b) Population Distribution and Estimated Maximum Wave Height based on Numerical Tsunami Simulation for the 2004.12.26

Figure 1. Estimated damage based on numerical tsunami simulation with possible fault scenarios along the Sunda Trench

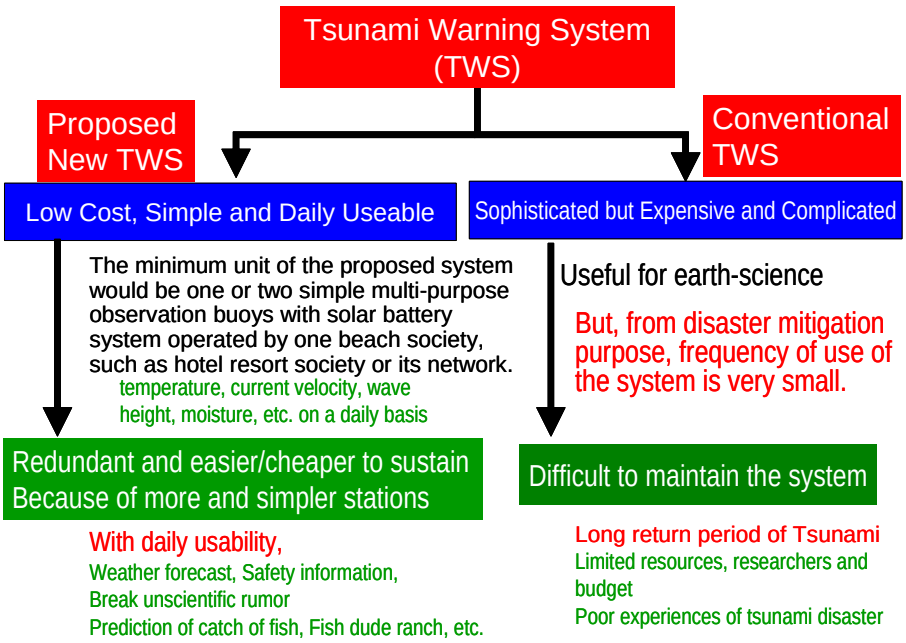


Figure 2. Comparison between conventional and newly proposed tsunami warning systems

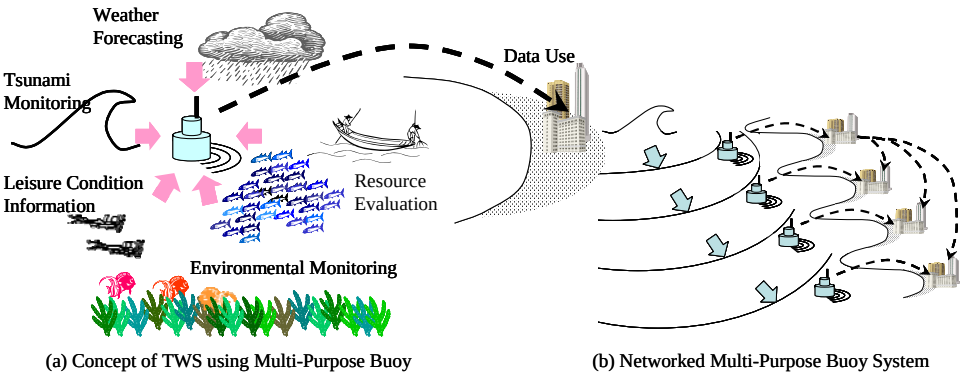


Figure 3. Concept of proposed tsunami warning system composed of networked simple multi-purposes observation buoys installed locally and internationally

2. PROPOSAL OF THE NEW TSUNAMI DISASTER MITIGATION SYSTEM

Our proposed New Tsunami Disaster Mitigation System combines a reliable warning system and proper evacuation facilities. As mentioned earlier, a warning system such as the one available in the Pacific Ocean Rim region is not suitable for the Indian Ocean region which has fewer technological resources, researchers and experiences of tsunami disasters. For this reason, we have proposed to use simple multi-purpose observation buoys, which in addition to serve as a tsunami warning system, would record temperature, current velocity, wave height, moisture, etc. on a daily basis. This information can be used for weather forecasting, safety assessment, fish catch prediction, etc. which are useful for the local businesses (**Figure 3(a)**). Our proposal is to use numerous and simple stations so that the system is redundant and easier/cheaper to sustain. The minimum unit of the proposed system would be one or two multi-purpose observation buoys operated and maintained by hotels or beach societies in the area. These businesses will benefit from the daily collected information.

It is expected that many beach societies install the system and join the multi-purpose observation buoy network beyond the administrative or international boundaries (**Figure 3(b)**). In this way, it may be possible to gather daily maritime information over a wider area and eventually forecast a transoceanic tsunami. A system for transferring this information between domestic and international associations already exists.

The installation of the proposed buoy system could have additional advantages. After the December 26, 2004 tsunami, the tourism industry has suffered greatly not only due to direct impact of the tsunami in the infrastructure but also due to the unscientific rumors. Visitors that used to come to resort facilities in the region started avoiding these destinations for fear that a new disaster may occur. In order to recover the tourists' trust, the information collected by the buoy system can be very useful. It is also known that buoys may become the center of marine ecosystems which could be an attraction for scuba divers.

Proper evacuation facilities in terms of location, strength and sheltering capacity are also part of the proposed system. In the region, it is common to observe mosques, temples, shrines and churches located in towns and villages along the coastal line. Therefore, we have proposed to use worship centers as evacuation facilities. This scheme has two main advantages. Because worship centers are permanently used by the people, their location is well known so that in case an evacuation notice is released, everybody can easily access them. Additionally, because the people feel strong commitment with these facilities, they take active participation in their building and maintenance.

3. ESTABLISHMENT OF THE PROPOSED TSUNAMI DISASTER MITIGATION SYSTEM

Figure 4 shows total research structure composed of five research topics that are listed below and are necessary to do for implementation of our proposed system. Japanese reconnaissance team, headed by the first author, carried out these five researches.

1) Structural damage survey
2) Tsunami numerical simulation
3) Topographical survey
4) Questionnaire/Interview survey
5) Evacuation numerical simulation

The first three activities are closely interrelated and their main objective is to design the configuration and location of evacuation centers. The structural damage survey is intended to evaluate the tsunami load and corresponding damage. With this information, the relationship between tsunami wave load and wave height/velocity can be obtained. With tsunami numerical simulations using potential earthquake scenarios, it is possible to estimate the wave height and velocity and the tsunami inundation area due to future tsunami hazards. These data enable us to properly determine location and structural design criteria for evacuation facilities.
In order to guaranty that the evacuation centers are fully functional, their location should be selected so that when the expected tsunami occurs they will not be washed away. For this purpose, it is indispensable to carry out a topographical survey. Real-time kinematic GPS and laser total stations are powerful tools for this purpose.
Questionnaire and interview surveys are useful to gather data necessary for the evacuation behavior simulation. Relationships between human evacuation velocity and water depth, which are needed for this study, have already been proposed. The simulation will confirm whether the escape routes and proposed evacuation centers are suitable. Because the proposed tsunami disaster mitigation system heavily relies on the participation of regional organizations, the interviews are also helpful to assess the level of acceptance of the system among the people involved.

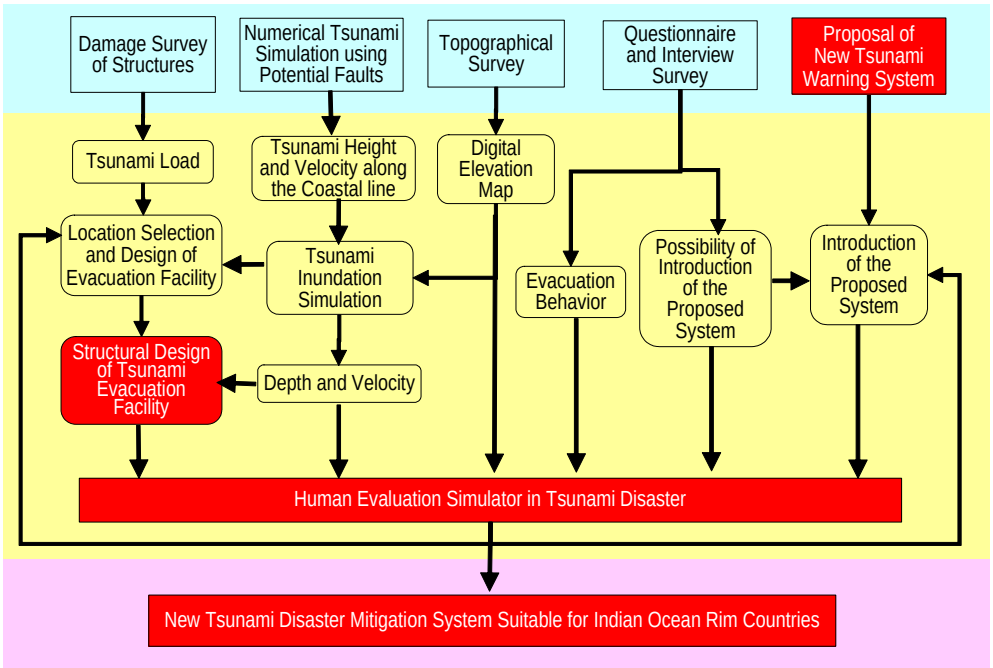


Figure 4. Establishment of the proposed tsunami disaster mitigation system

Figure 5 shows some samples of multi-purpose observation buoys that we have developed. With the solar panel system installed on the buoy, the system can continue observation permanently and users can get their favorite information with real-time basis. Initial cost of the system is about 10 to 20 million yen (changing with the equipments that the user wants to install the buoy). As we think that potential users of the system are resort hotel owners in beach resort as they can get the biggest benefit, when we calculate the additional cost (yen/room/day) to the normal room rate that is necessary for maintaining the system, we can get the numbers shown in **Table 1**. The numbers in **Table 1** are obtained by assuming that life time of the system is 3 to 5 years, average number of rooms in each resort beach is 200 to 500 rooms, and average number of days of use of the room is 100 to 200 days/year. From the numbers in **Table 1**, we can say that with reasonably low additional cost, our proposed system can be maintained.

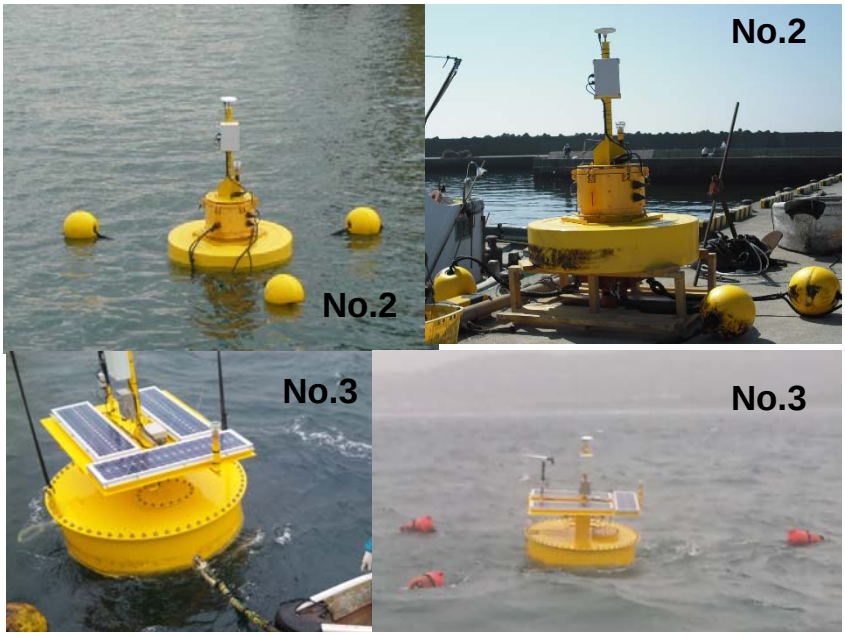


Figure 5. Samples of developed systems

Table 1. Cost needed to maintain the system (yen/room/day)

Cost (mill. yen)	Life time (years)	200 rooms/beach		500 rooms/beach	
		100 days	200 days	100 days	200 days
10	3	167	83	67	33
	5	100	50	40	20
20	3	333	167	133	67
	5	200	100	80	40

4. CONCLUDING REMARKS

This paper presents a New Tsunami Disaster Mitigation System for the Indian Ocean Rim region, which combines a reliable warning system and proper evacuation facilities. The warning system consists of multi-purpose observation buoys operated by local organizations such as hotels and beach associations. The system is not only used for tsunami warning but also to monitor temperature, current

velocity, wave height, moisture, etc., information which can be used on a daily basis for the economic activities of the region.

The proposed evacuation facilities are designed taking into consideration: sheltering capacity, location, and structural strength. Location is especially important to prevent that the structures are washed away by the tsunami and to guaranty an easy access for the evacuees.

In order to verify the suitability of the proposed system, tsunami and evacuation simulations are recommended. Actually, the research team headed by the author has already perform this type of study with some selected areas in Japan and Sri Lanka and proved the system effectiveness. The strong points of the proposed system are its simplicity, economy and daily usability, which makes it a sustainable option for the region.

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