Analysis of the Effectiveness of Early Warning System to Face Future Tsunamis in Sri Lanka by comparing with Japanese Early warning system.

Sri Lanka

FREFACE

Over the last quarter of the century in the world has experienced many Tsunamis. Thousands of people were dead due to improper warning dissemination mechanism. This is the one of attempts to save the life in the World. By Ravi Jayarathne

J.M.A.R. Jayarathne Deputy Director Emergency Operation Sri Lanka

Disclaimer

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Dedication

I dedicate this research to the Disaster Management Centre, ADRC, My family, and my Parents, who thought us to think, understand and express. I earnestly feel that without their inspiration, able guidance and dedication, I would not be able to achieve through the tiring process of this research. I might not know where the life's road will take me, but Walking with you, through this journey has given me the full Strength. Thanks for inspiring my life.

Acknowledgement

I wish to take this opportunity to convey the gratitude of the government of Sri Lanka to the government and the peoples of Japan and in particular to the ADRC and respective organization and institution of disaster management for the assistance provide to me. I hope that they will continue to assist and collaboration between us in the area of disaster management and early warning in the future. And also I would like to give my sincere gratitude to Hon. Anura Priyadarshana Yapa Minister to the Ministry of Disaster Management, Mr. S. S. Miyanawala Secretary to Ministry of Disaster Management, G.L.S Senadeera Director General to the Disaster Management Centre, Major General Gamini Hettiarchchi, Major General LBR Mark former Director generals of Disaster Management Center, Prof. Masanori Hamada chairman ADRC, Mrs. Kyoko Kondo Executive Director ADRC Kobe and my mentors Mrs. Miki Kodama Senior Researcher, Mr. Makota Ikeda. My special thanks goes to Mrs. Yumi Shiomi for assisting, coordinating of all arrangement for success of my research in Japan. Finally, I gratitude to ADRC staff and those who are encouraged me in various way.

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(J.M.A.R. Jayarathne)
(Disaster Management Center, Ministry of Disaster Management)
(Sri Lanka)

ADRC Visiting Researcher FY2016B

Analysis of the Effectiveness of Early Warning System to Face Future Tsunamis in Sri Lanka by comparing with Japanese Early warning system.

Abstract

On December 26 2004, about 4/5 of the costal belt of Sri Lanka was affected by a Tsunami which occurred due to an earthquake off west coast of north Sumatra Islands. The location of the epicentre of this earthquake was at 3.2N and 95.82E at a depth of 30 km below mean sea level. The quake that occurred at 6:58:53 Sri Lankan time had a magnitude of 9.0 in Richter scale. Humans were confronted by an unprecedented catastrophe impacting the lives of people not only in the Indian Ocean region but all over the world. The death toll is believed to be over 270,000 people with billions of dollars in damage cost. It is widely acknowledged that if effective Early Warning System had been in place in the Indian Ocean region, thousands of people could have been saved. The present Early Warning System has designed for communicate from national level to district / divisional /Grama Niladhari levels. The Early Warning towers, radio communication system, SMS and Cell broadcast system, fax, e-mail, inter government network, VPN line, social media are main sources of communication system already been established in the country. In addition to above communication system the police and military communication systems, media and the land line telephone systems are utilised directly and indirectly for communication and coordination of disasters. Main initiatives were taken by the Disaster Management centre which was established after the Tsunami in 2004. Over a decade, many systems and activities provided to enhance the Tsunami Early Warning System in Sri Lanka. Two times tsunami evacuations (2007 & 2012) and one Tsunami warning (2011) were issued after the 2004 up to now. A tsunami warning system (TWS) is used to warn coastal communities in advance and issue warnings to prevent loss of life and property damages. Meteorological Department which is national warning cater (NWC) issue the warning and Disaster Management Centre is being disseminate those messages from national level to local level.

The islands of Japan are located in a volcanic zone on the Pacific Ring of Fire. Destructive earthquakes, often resulting in tsunami, occur several times each century. The 1923 Tokyo earthquake killed over 140,000 people. More recent major quakes are the 1995 Great Hanshin earthquake and the 2011 Tōhoku earthquake, a 9.0-magnitude quake which hit Japan on March 11, 2011, and triggered a large tsunami. Due to its location in the Pacific Ring of Fire, Japan is substantially prone to earthquakes and tsunami, having the highest natural disaster risk in the developed world. Japan is a developed country thus the Sri Lanka is developing country. However, Save the people in the world from the disasters that should not be the issue. Therefore, this study would be attempted to measure the effectiveness of the current systems of both countries and it will facilitate the future developments for the Tsunami early warning.

The study was identified the issues in both countries and forwarded the recommendations such as, Japan has to be developed a traffic plan and it should be integrated with the early warning system to ensure the evacuation of the vulnerable communities due to high density of costal population and when the earth quake magnitude is more than 07, the population of the 01 kilometer from the beach should be evacuated to the safer location with their vehicles within 05 – 10 minutes and if they unable to evacuate within given time, aware the people to evacuate without vehicles in order to avoid traffic jam, The Japan has to enhanced the awareness of the early warning systems, channels, mechanisms and type and kind of early warning massagers which are going to be send the communities, Japan is being disseminated several messages to general public and vulnerable communities. Therefore, each and every people could not be taken appropriate decision. In order to reduce this panic situation before the relevant time, Japan has to reduce the number of advisory, alert, warning messages. People do not need earthquake messages, magnitude, epicenter, etc. when consider the tsunami. Japan has to emphasized to the communities on evacuation message as soon as possible due to limited time for tsunamis, Japan has to be improved the conventional communication system to response even during the night time. Early warning towers and other system could not be explained the evacuation locations and further additional details, in such situation conventional mechanism are important to guide the people until reach to safe locations. Therefore, Megaphone, public address systems etc, has to be ready in appropriate locations, Japan has more than 60 % elderly peoples. They are taken more than 15 minutes to evacuate to the safe location by foot. Most of elderly and different abled people will die due to tsunami while they are moving to safe location and lack of awareness on early warning. In order to prevent such situation, Evacuation messages has to disseminated as soon as possible, Japan ordinary used Japanese language to warn the communities but japan has to take keen attention about foreign delegates who are working in the japan. Therefore,

japan has to provided warning message at least English language too like "Tsunami, Tsunami, please Evacuate, Evacuate".

Sri Lanka has to improve the dedicated communication system with the regional warning centers between the national tsunami warning center to avoid the communication interruption. Sri Lankan peoples could not get the earthquake feeling where Sri Lanka is not locating in the earthquake fault or Ring of fire, Sri Lanka has cultural and social impacts for early warning specially language and giving night time evacuation order. The women cannot be seen in the night around 7pm due to transport barriers, less security, culture itself refuse to see the women in the night, dependence are not allowed etc, therefor Sri Lanka has to do the in the night time by using early warning system to avoid the such situation. Only the early warning towers has provided messages by three languages. But each and every warning messages has to be disseminate by "Sinhala, Tamil, English" language in order to prevent the language barriers in Sri Lanka and thus each administrative levels have to be kept in ready the prerecorded warning messages to disseminate at the disasters, Sri Lanka has been struggling with new technology involvement after established with the early warning system in 2009. Sri Lanka has to hired the technology from the original suppliers and it has to upgrade by time to time expending high cost. It is highly recommending to integrate with local technologies which can be sustained and effective by corporate with technical institutes, The Sri Lanka has a well-established early warning system. Though it is well established, there is no any dedicated channel to conform the dissemination and reception of the message. Sri Lanka is being utilized many other channels which are military, police, etc. to overcome the current gap of early warning system. It is recommended to arrange a dedicated line with several locations to get the feedback of early warning messages, After the great 2004 tsunami the word "TSUNAMI" is famous in the country. But science, aptitude of the hazard and many other response activates are not known by many other communities in the middle part of the country. Awareness on tsunami has to be provided and enhanced to the communities in order to save the life from future tsunamis.

Chapter I - Introduction

There is a growing recognition among many countries that natural disasters increasingly constitute a threat to sustainable development. The impact of natural disasters on vulnerable communities is increase in rate. In 2004 Tsunami tragedy occurred in the Asian region and there was not any early warning mechanism to save the people lives. Therefore, more than 30,000 people were died in Sri Lanka. Because of that government establish the Disaster Management Centre (DMC) for coordinate with other stakeholders to prevention, mitigation, preparedness, training & public awareness and response in the impending disasters.
One of the functions of the DMC has identified as community early warning and dissemination through the early warning systems. Therefore, DMC has been strengthening the early warning system by using various technologies such as establishing of early warning towers, supply of distribution of sirens and public addressing systems, SMS and cell broadcast system, etc. But prior to beginning of all these systems in Sri Lanka, there were traditional warning mechanism for various disasters. At the present all traditional and new technological systems are integrated to get the maximum benefit to the community early warning.

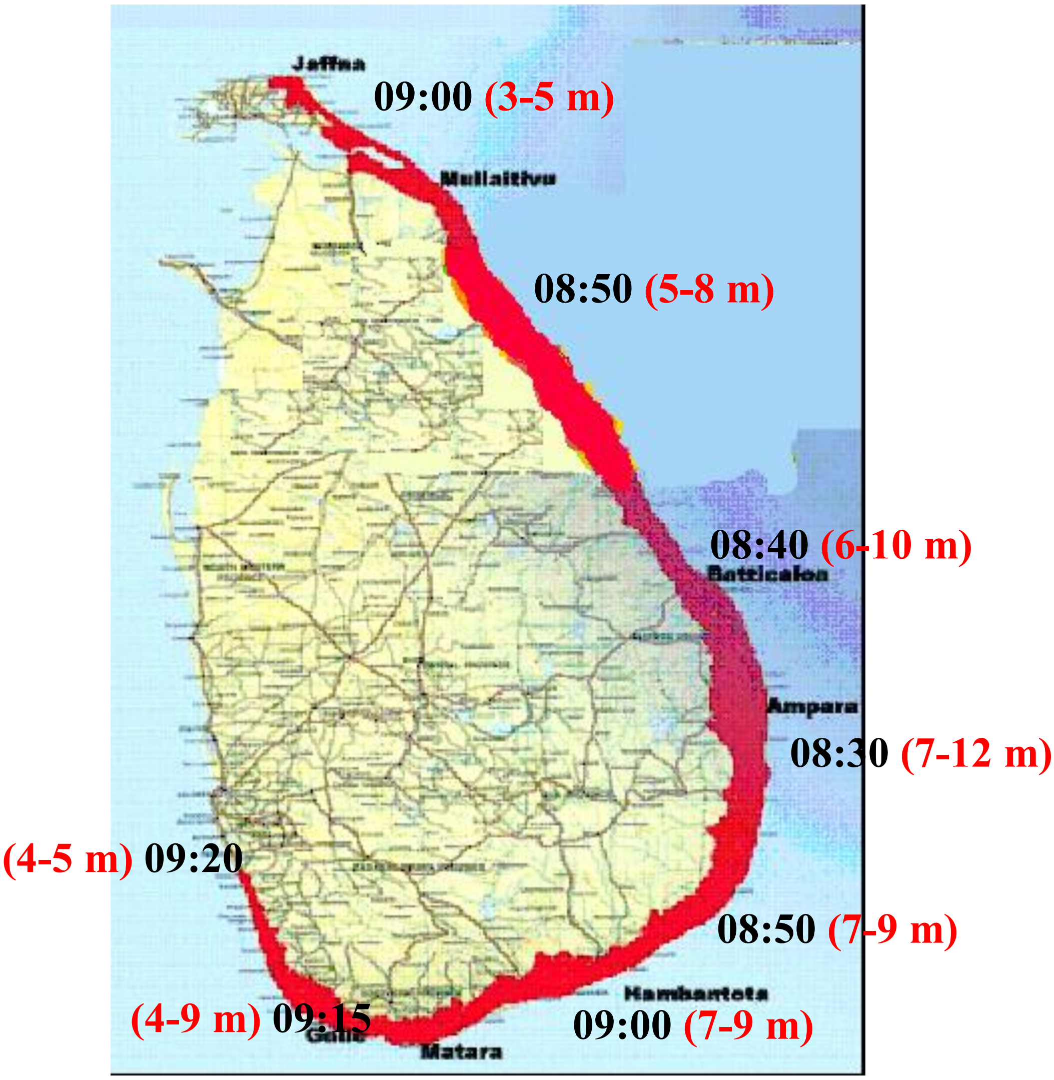


Figure 1: Tsunami hit to the coast of Sri Lanka

A tsunami is generated when a large amount of water is displaced very quickly. When the earthquake occurred outside of Sumatra, the Indo Australian tectonic plate moved 20 meters below the Eurasian tectonic plate. This is called subduction. This caused the Eurasian plate to thrust up several meters. This earthquake also created submarine landslides. Events such as submarine earthquakes and landslides release a colossal amount of energy that is transferred to the surrounding water. An ocean wave is not moving water, but energy that is passing through water. The water particles do not move, but they transfer energy to the next particle of water. In deep water, a tsunami's energy is mostly located below the sea surface and the wave height is just a couple of meters. This is why ships on the open ocean usually don't move much when a tsunami passes beneath. In deep water, tsunamis can travel at speeds. When the tsunami moves into shallower water, however, its enormous energy is concentrated within a smaller volume. This yields waves of greater height and slower speed. The contours of the sea floor and the coastline greatly influence the tsunami wave. The height of the tsunami waves that came to shore in the 2004 Indian Ocean tsunami were between 24 and 30 m high.

Mostly many developments and civilization is occurring in the coastal areas. Tourism industry is booming in the coastal areas. Therefore, to save the coastal communities, there should be a timely and effective early warring mechanism from the national level to the village levels. After the introduction of the early warning system around 10 years ago in Sri Lanka, it has not been validated. This research will facilitate to clarify the current issues and identify solutions in the early warning system in Sri Lanka with compare to the Japan.

On December 26 2004, an earthquake measuring 9.0 on the Richter scale struck the western coast of Sumatra in Indonesia triggering massive ocean waves or “tsunamis”. Humans were confronted by an unprecedented catastrophe impacting the lives of people not only in the Indian Ocean region but all over the world. The death toll is believed to be over 270,000 people with billions of dollars in damage cost. While many people are believed to have died in the earthquake, the main cause of death was trauma and drowning from the flux of seawater and waves pouring into coastal areas without warning.

It is widely acknowledged that if effective early warning systems had been in place in the Indian Ocean region, the death toll would have been drastically reduced While a relationship between local, felt earthquakes and tsunamis was realized in ancient times in many societies, it was much later in human history that it was realized that destructive tsunamis can propagate great distances, far beyond the range of human perceptibility of the causative earthquake. The present system of communication from national level to district / divisional / local authority / Grama Niladari levels or other specific identified locations is mainly through the Police and military communication systems, radio communication, multi-hazard early warning towers, media and the normal telephone systems. Alternative coastal wide communication systems already been established for the Tsunami disaster. Main initiatives were taken by the Disaster Management center which was established after the Tsunami in 2004.Over a decade, many systems and activities provided to enhance the Tsunami Early Warning System in Sri Lanka. 2 Tsunami evacuations (2007 & 2012) and one Tsunami warning (2011) were issued after the 2004 up to now. A tsunami warning system (TWS) is used to warn coastal communities in advance and issue warnings to prevent loss of life and damages. Meteorological Department issue the warning and Disaster Management Centre is catering all communications from national level to the local level but up to now No studies had conducted to evaluate the current early warning system for the tsunami disaster.

It is essential to ensure capacity of the Early Warning system to save more than 2 million lives along the coastal area of Sri Lanka. Gaps of disseminating and community reception at night time also been identified. But up to now there is no any studies had been conducted to evaluate the current early warning system for the tsunami disaster in Sri Lanka. It is essential to ensure the capacity of the Early Warning system is sufficient to save the people who are living along the coastal belt of Sri Lanka.

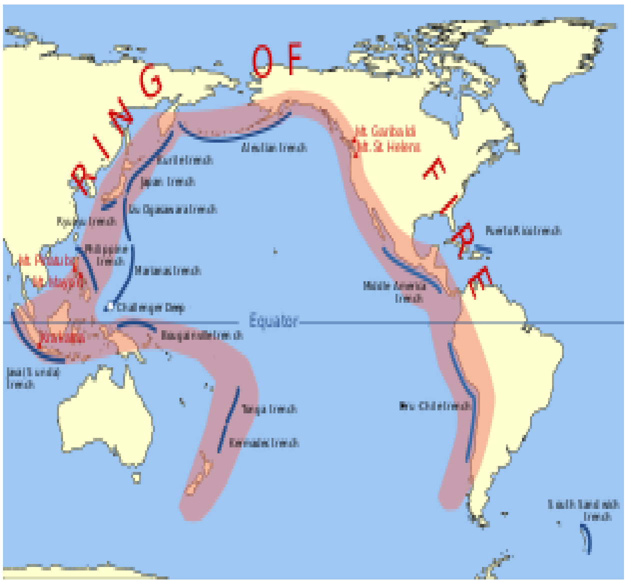
Japan is an island nation in East Asia. Located in the Pacific Ocean, it lies to the east of the Sea of Japan, People's Republic of China, North Korea, South Korea and Russia, stretching from the Sea of Okhotsk in the north to the East China Sea and Taiwan in the south. The characters that make up Japan's name mean "sunorigin", which is why Japan is sometimes referred to as the "Land of the Rising Sun".

Japan is an archipelago of 6,852 islands. The four largest islands are Honshu, Hokkaido, Kyushu, and Shikoku, which together comprise about ninety-seven percent of Japan's land area. With over 127 million people Japan has the world's tenth-largest population.

Figure 2: Japan surrounded by sea and Topology of japan

The islands of Japan are located in a volcanic zone on the Pacific Ring of Fire. They are primarily the result of large oceanic movements occurring over hundreds of millions of years from the mid-Silurian to the Pleistocene as a result of the subduction of the Philippine Sea Plate beneath the continental Amurian Plate and Okinawa Plate to the south, and subduction of the Pacific Plate under the Okhotsk Plate to the north. Japan was originally attached to the eastern coast of the Eurasian continent. The subducting plates pulled Japan eastward, opening the Sea of Japan around 15 million years ago.

Japan has 108 active volcanoes. Destructive earthquakes, often resulting in tsunami, occur several times each century. The 1923 Tokyo earthquake killed over 140,000 people. More recent major quakes are the 1995 Great Hanshin earthquake and the 2011 Tōhoku earthquake, a 9.0-magnitude quake which hit Japan on March 11, 2011, and triggered a large tsunami. Due to its location in the Pacific Ring of Fire, Japan is substantially prone to earthquakes and tsunami, having the highest natural disaster risk in the developed world.



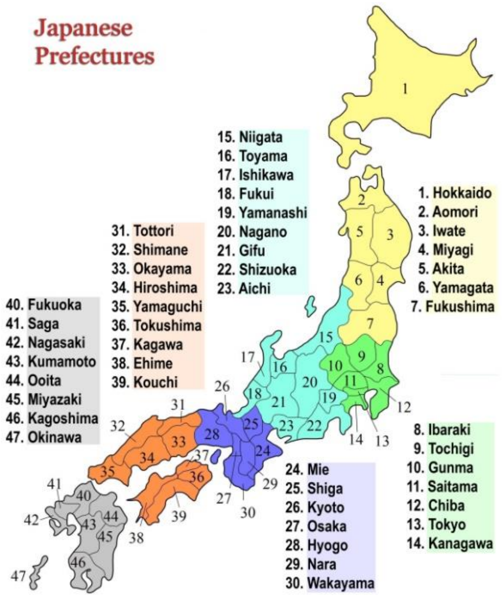


Figure 3: Ring of Fire and Japanese prefectures

Greater Tokyo Area, which includes the de facto capital city of Tokyo and several surrounding prefectures, is the largest metropolitan area in the world, with over 30 million residents. About 73 percent of Japan is forested, mountainous, and unsuitable for agricultural, industrial, or residential use. As a result, the habitable zones, mainly located in coastal areas, are highly populated. Making Japan as one of the most populated countries in the world.

Japan's geographical and climatologically the country is vulnerable to frequent natural disasters such as typhoons, torrential rains and heavy snow as well as earthquake, Tsunamis and volcanic eruptions. Japan is located in the circum-Pacific mobile zone where seismic and volcanic activities occur constantly.

Although the country covers only 0.25% of the land area on the planet, the number of earthquakes and distribution of active volcanoes is quite high. Due to the geological formation with plate boundaries of the Pacific plate, the Philippine Sea plate, the Eurasian plate, and the North American plate, Japan is substantially prone to earthquakes and tsunami, having the highest natural disaster risk in the developed world.

Every year there is a great loss of people's lives and properties due to natural disasters. As such natural disasters remain a menacing threat to safety and security of the country. However, with the progress of society's capacity to address disasters and mitigation of vulnerabilities to disasters by developing disaster management systems, promoting national land conservation, improving weather forecasting technologies and upgrading disaster information communication systems, disaster damage has shown a declining tendency.

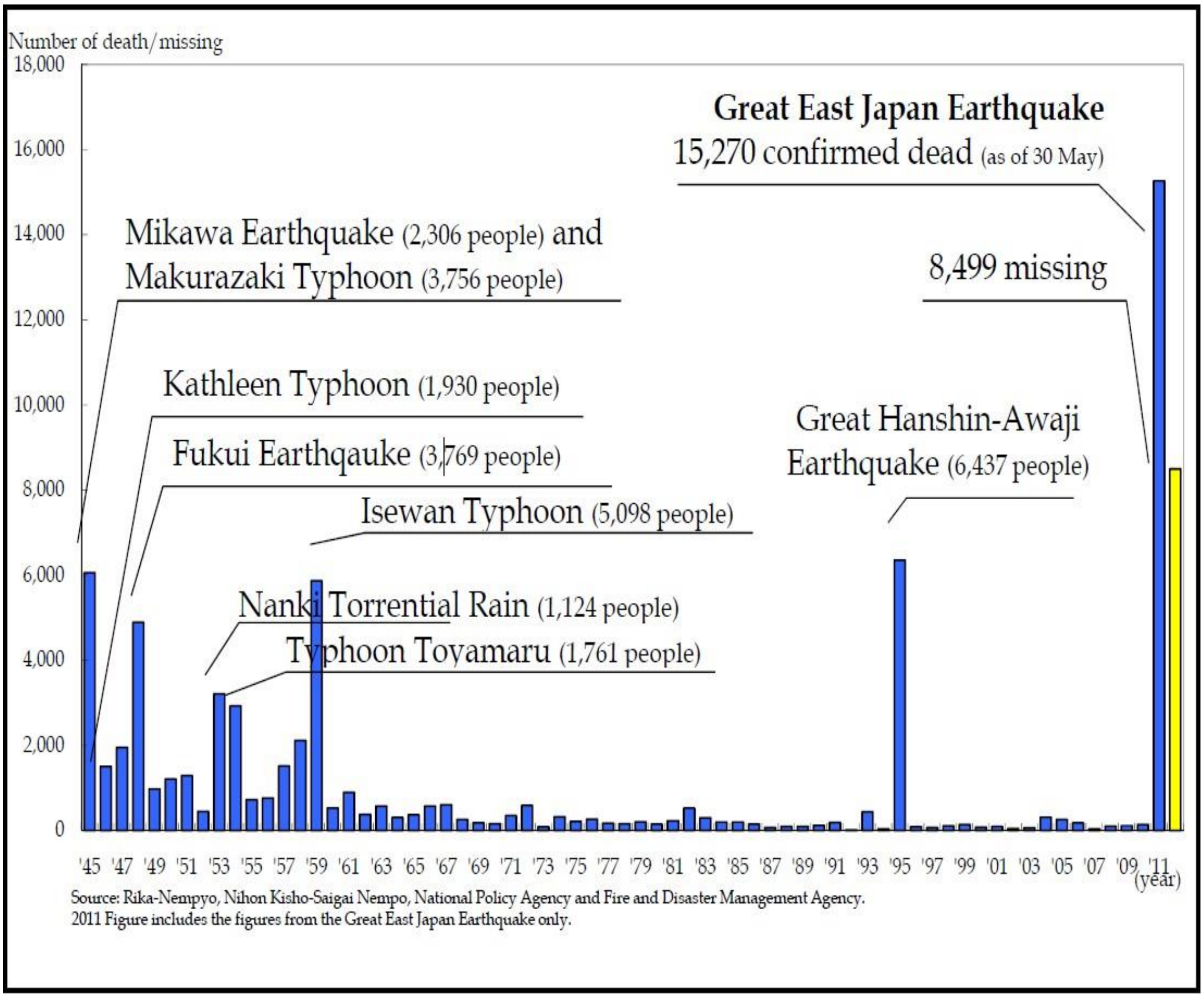


Figure 4: Loss of life due to natural disasters science 1945

The japan has many experienced on disaster management and Early warning to the public with comparing to the Sri Lanka. However, Sri Lanka has been established an early warning mechanism to address the impending disasters after grate tsunami 2004. Japan is a developed country thus the Sri Lanka is developing country. However, Save the people in the world from the disasters that should not be the issue. Therefore, this study would be attempted to measure the effectiveness of the current systems of both countries and it will facilitate the future developments for the Tsunami early warning.

1.1 Disaster Management Mechanism in Sri Lanka

Ministry of Disaster Management is the one of vital important ministry in the country which is mandated for disaster management activities. Disaster Management Centre, National Disaster Relief Service Centre, National Building Research Organization and Department of Meteorology are being functioning under the Ministry of Disaster Management. The main administration system for disaster management of the country operates under the central government and through the Ministry of Disaster Management.

Link for more details- http://www.disastermin.gov.lk/web/

The National Policy on Disaster Management (the 'Policy') is a core component of Sri Lanka's national regime for disaster management. It articulates agreed overarching principles and preferred outcomes for disaster management in Sri Lanka. It also provides policy directives to address the issues such as inadequate coordination among stakeholder agencies, duplication of efforts and insufficient policy directives to reduce the human and economic impacts of disasters which were identified in the aftermath of the 2004 Tsunami and the other recent disaster situations.

The 2005 Parliament Select Committee on Natural Disasters recommended formulation of a national policy to manage disasters after the 2004 Indian Ocean tsunami. The Disaster Management Act, No.13 of 2005 (the 'Act') provides that the National Council for Disaster Management (the 'Council') shall formulate such a policy.1 Its preparation was the first listed of 60 outcomes for the period 2006-2016 under the document Towards a Safer Sri Lanka: A Road Map for Disaster Management ('the Road Map'). In accordance with the Road Map, the Ministry of Disaster Management, as Secretariat of the Council, led a consultative process to formulate the Policy with input and guidance from relevant agencies and stakeholders. More details please access the fallowing link. http://www.disastermin.gov.lk

The Sri Lanka Disaster Management Act No.13 of 2005 is the main legal document for disaster management in Sri Lanka and it was enacted in July 2005 which provides the legal basis for instituting a disaster risk management system in the country. The National Council for Disaster Management (NCDM) is a high-level policy making body for safe the country from any calamities. The chairman and vice chairman of the NCDM is H.E. The President and Hon Prime Minister respectively. Other members are Leader of the Opposition, Ministers in charge of 20 selected subject areas, Provincial Council Chief Ministers and five members of the Opposition. The Act also provides for establishing the Disaster Management Centre (DMC) under the Council to be the apex body for the purpose of planning, co-coordinating and implementing of certain natural and other forms of disasters.

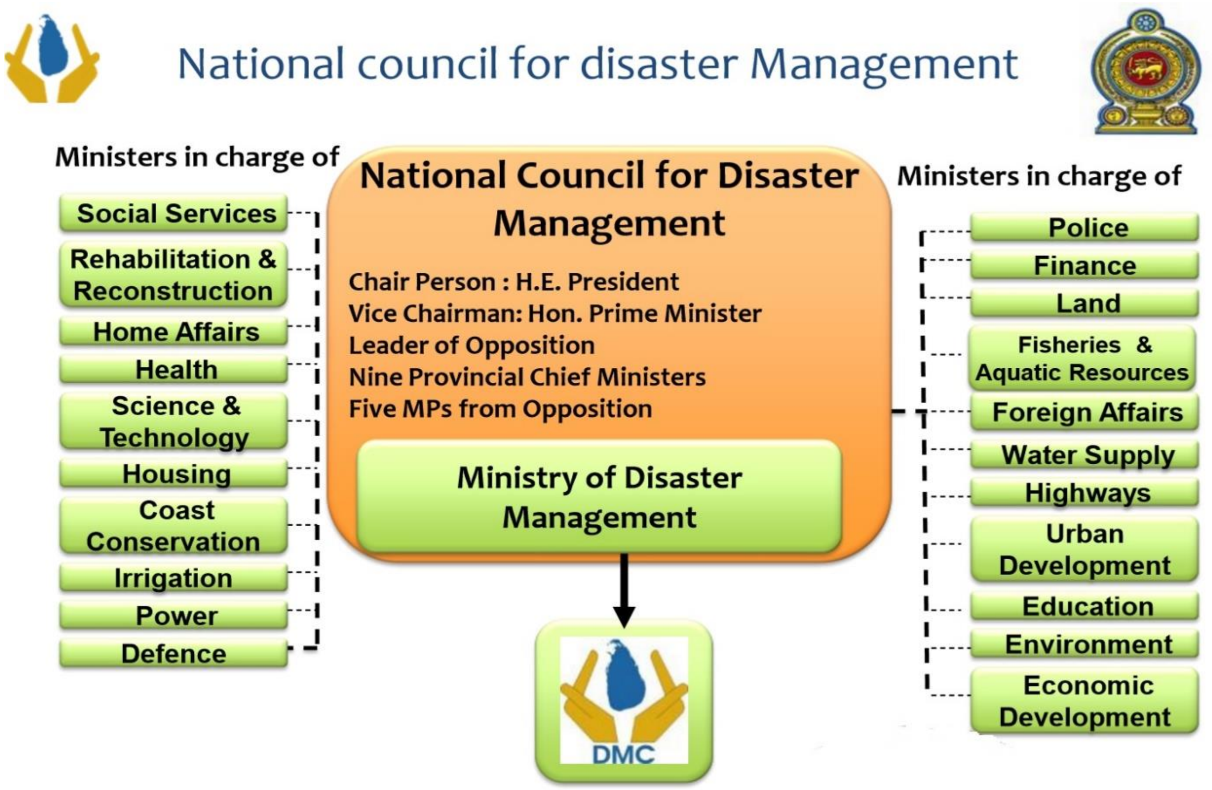


Figure 5: Structure of National Disaster Management Council

Sri Lanka Disaster Management Act No.13 of 2005 provides for a framework for DRM in Sri Lanka and addresses Disaster Management (DM) holistically, leading to a policy shift from response based mechanisms to a proactive approach towards disaster risk reduction (DRR). Twenty-one hazards come under the purview of the act. More details please access the fallowing link.
Link- http://www.dmc.gov.lk/attchments/DM%20Act%20English.pdf

1.2 Disaster Management Mechanism in Japan

a. Legal and Institutional Framework of Japan

In Japan, the DM system has been developed and strengthened following the bitter experience of large-scale natural disasters and accidents over the years. The country has 7 basic acts, 18 disaster prevention and preparedness legislations, 3 legislations governing disaster emergency response and 23 disaster recovery and reconstruction and financial measures acts. The first act i.e. Disaster Relief Act dates back to 1947 passed after the 1946 Nankai earthquake. Thereafter every disaster led to learning and experience and it led to passing of new legislation. There is almost a separate legislation for each disaster and separate legislation for every aspect of disasters such as prevention, preparedness, response, rehabilitation and recovery, building standard, financial measures, earthquake insurance, etc.

The turning point for strengthening the disaster management system came after the immense damage caused by the Ise-wan Typhoon in 1959, and led to the enactment of the Disaster Countermeasures Basic Act in 1961, which formulates a comprehensive and strategic disaster management system in Japan. The DM system has further been strengthened following the lessons learnt from large-scale disasters such as the Great Hanshin-Awaji Earthquake, 1995. The learning of the 2011 Great East Japan Earthquake and Tsunami (GEJET) and nuclear disaster has been incorporated in the Disaster Countermeasures Basic Act by amending it in June, 2012 and by making changes in Basic Disaster Management Plan in December, 2011. The most notable piece of legislation is the Act passed in 2002 namely 'Act on Special Measures for Promotion of Tonankai and Nankai Earthquake Disaster Management'. The country is expecting big earthquake which may arise out of Tonankai and Nankai troughs and this legislation aims at reducing possible impact from these earthquakes and preparing the country to face them.

b. The names of different act and circulars Japanese government issued time to time for various kinds of disaster issues

1. Erosion Control Act (1897)
2. Building Standard Law (1950)
3. Forest Act (1951)
4. Act on Temporary Measures for Disaster Prevention and Development of Special Land Areas (1952)
5. Meteorological Services Act (1952)
6. Seashore Act (1956)
7. Landslide Prevention Act (1958)
8. Act on Special Measures for Disaster Prevention in Typhoon-prone Areas (1958)
9. Act on Special Measures for Heavy Snowfall Areas (1962)
10. River Act (1964)
11. Act on Prevention of Steep Slope Collapse Disaster (1969)
12. Act on Special Measures for Active Volcanoes (1973)
13. Act on Special Financial Measures for Urgent Earthquake Countermeasure Improvement Projects in Areas for Intensified Measures (1980)
14. Act on Special Measures for Earthquake Disaster Countermeasures (1995)
15. Act on Promotion of the Earthquake-proof Retrofit of Buildings (1995)
16. Act on Promotion of Disaster Resilience Improvement in Densely Inhabited Areas (1997)
17. Act on Promotion of Sediment Disaster Countermeasures for Sediment Disaster Prone Areas (2000)
18. Specified Urban River Inundation Countermeasures Act (2003) Vicinity of the Japan and Chishima Trenches (2004)

c. Basic Acts

1. Disaster Countermeasures Basic Act (1961)
2. Act on Prevention of Marine Pollution and Maritime Disaster (1970)
3. Act on Disaster Prevention in Petroleum Industrial Complexes and other Petroleum Facilities (1975)

4. Act on Special Measures for Large-scale Earthquakes (1978)
5. Act on Special Measures for Nuclear Disasters (1999)
6. Act on Special Measures for Promotion of Tonankai and Nankai Earthquake Disaster Management (2002)

Act on Special Measures for Promotion of Disaster Management for Trench-type Earthquakes in the Disaster countermeasures basic act is the strong act was created at that time considering all the issues and lesson learnt experience. In 1959 Ise-Wan typhoon was the major calamity to think on develop the disaster countermeasure basic act which is still powerful tool for disaster management activities.

At the national level Central Disaster Management Council, the apex body for DM in Japan is housed within the Cabinet Office headed by the Prime Minister. Along with a series of reforms of the central government system in 2001, the post of Minister of State for DM was newly established to integrate and coordinate disaster reduction policies and measures of ministries and agencies. In the Cabinet Office, which is responsible for securing cooperation and collaboration among related government organizations in the wide-razing issues, the Director-General of Disaster Management is mandated to undertake the planning of basic disaster management policies and response to large-scale disasters, as well as conduct overall coordination.

Additionally, taking into account the lessons learned from the Great Hanshin-Awaji Earthquake, 1995, the Cabinet Secretariat system was also strengthened, including the appointment of the Deputy Chief Cabinet Secretary for Crisis Management and the establishment of the Cabinet Information Collection Center, to strengthen risk management functions to address emergencies such as large-scale disasters and serious accidents.

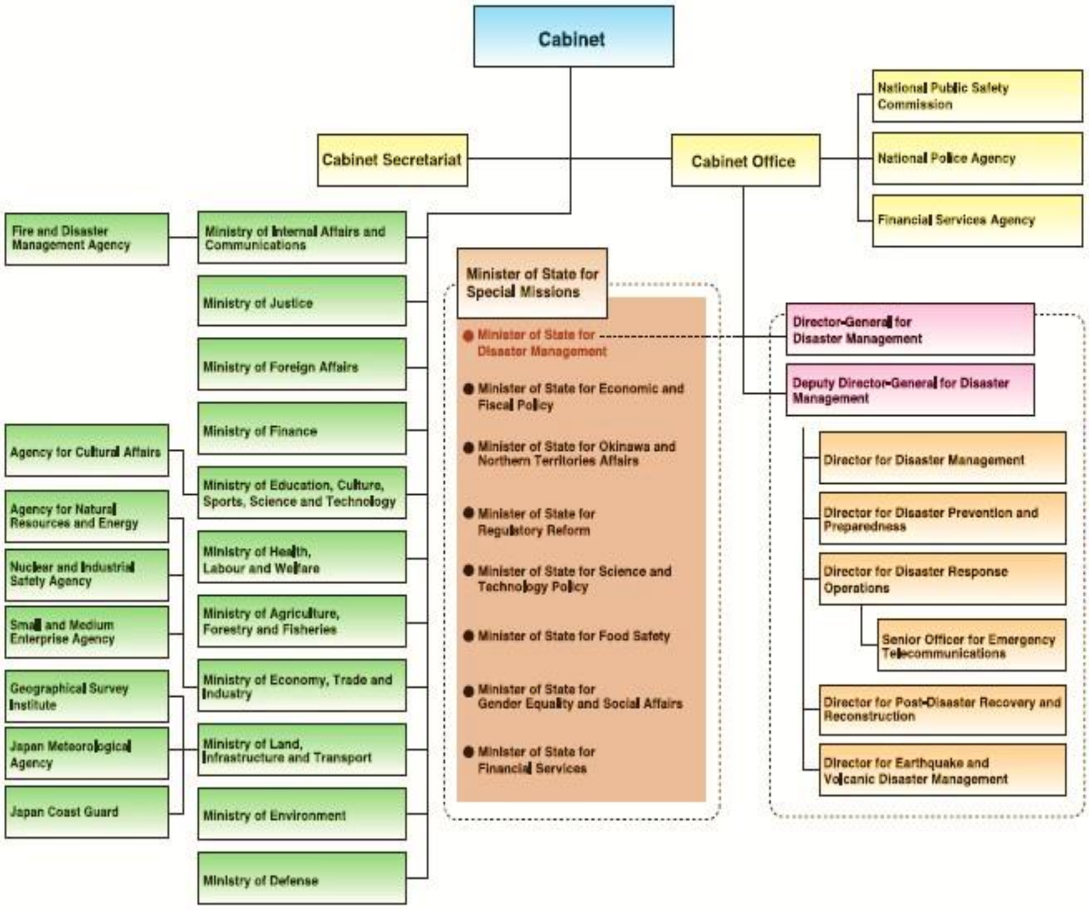


Figure 6: Organization of National Government and Cabinet Office (Disaster management)
Source: Cabinet Office, Government of Japan

d. Disaster Management Planning System in Japan

In Japan Disaster Management Planning is done at three levels namely: -

Disaster Management of Japan is categorized into 3 levels including national, regional and municipal level. The significance of each level is delineated as follows:

1) National Level: The Prime Minister is the National Commander through the National Disaster
Management Council, and the designed government organizations (23 ministries and agencies), and designated public cooperation (63 organizations including independent administrative agencies, Bank of Japan, Japanese Red Cross Society, NHK, electricity and gas companies and NTT). In this connection, the national council is responsible for formulation and promoting the implementation of the Basic Disaster Management Plan. Meanwhile, the other two designed agencies of government and public cooperation are responsible for formulation and implementation of the Disaster Management Operation Plan.

2) Prefectural Level: The Governor is the commander ordering via the Prefectural Disaster Management Council, and designed government organization and public corporations in local. The prefectural council will conjunctionally work with the mentioned designed agencies to formulate and promote the implementation of Local Disaster Management Plan.

3) Municipal Level: In this level, the Mayor of City, Town and Village is the commander, as the same of Governor in prefectural level, will take function through Municipal Disaster Management Council to formulate and promote the implementation of Local Disaster Management Plan.
The plans at all levels have been prepared and regularly revised and updated incorporating the lessons learnt and changes made in the Basic DMP prepared at the national level. DMP is the main document which is referred to for disaster management and emergency response.

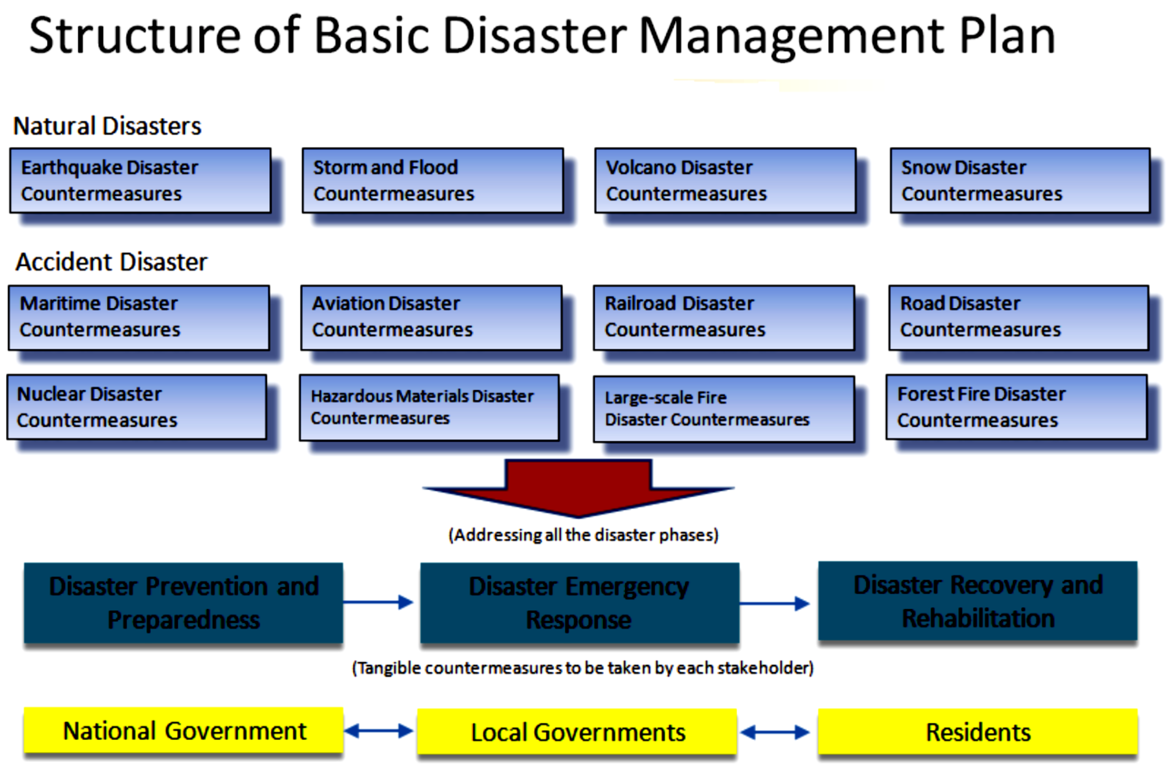


Figure 7: Structure of Basic Disaster Management Plan

e. A Data Collection and Processing System for Assured Communication

Japan is hyperaware of its shaky ground. The country withstands some thousand tremors a year, and they've got 180 seismographs and 600 seismic intensity meters constantly tuned to what's going on in the underworld. They also have around 30 sea level gauges operated by the coast guard and around 80 operated by the JMA that work in chorus to provide feedback to a Data Processing and Communication system. The sensors take a reading, upload it to a central processing system using old-fashioned wires and/or satellite uplink, and that central system sends updates to the government, police, coast guard, telephone companies, and the media. Sea level gauges also report disturbances in real time and help organizations model trajectory and size of the oncoming waves.

And then there are more specialized tools. There are tsunami detection buoys that help rule out false alarms and give monitoring agencies a better idea of what they're in for – or what they're not. Deep Ocean Assessment and Reporting of Tsunami system, is made up of an anchored sea floor bottom pressure recorder and accompanying fiberglass and foam buoy on the surface. The recorder on the ocean floor, which takes a note of temperature and pressure every 15 seconds, sends data via an acoustic link to the surface buoy. The buoy then sends information by satellite to Tsunami warning centers.

JMA monitors seismic activity and issues Warnings/Advisories and information on a 24-hour basis. To provide these resources urgently and precisely, JMA needs to collect various seismic data and analyze them quickly. To this end, the Agency operates a comprehensive system called EPOS (the Earthquake Phenomena Observation System). This is responsible for issuing Earthquake Early Warnings, Tsunami Warnings/Advisories, and Earthquake Information.

Warnings/Advisories and information issued by JMA are transmitted to disaster management authorities, local governments and the broadcasting media over a nationwide computer network immediately. Disaster management authorities and local governments take action to mitigate disasters based on these resources. Such action is also announced to the public through the media and the Internet.

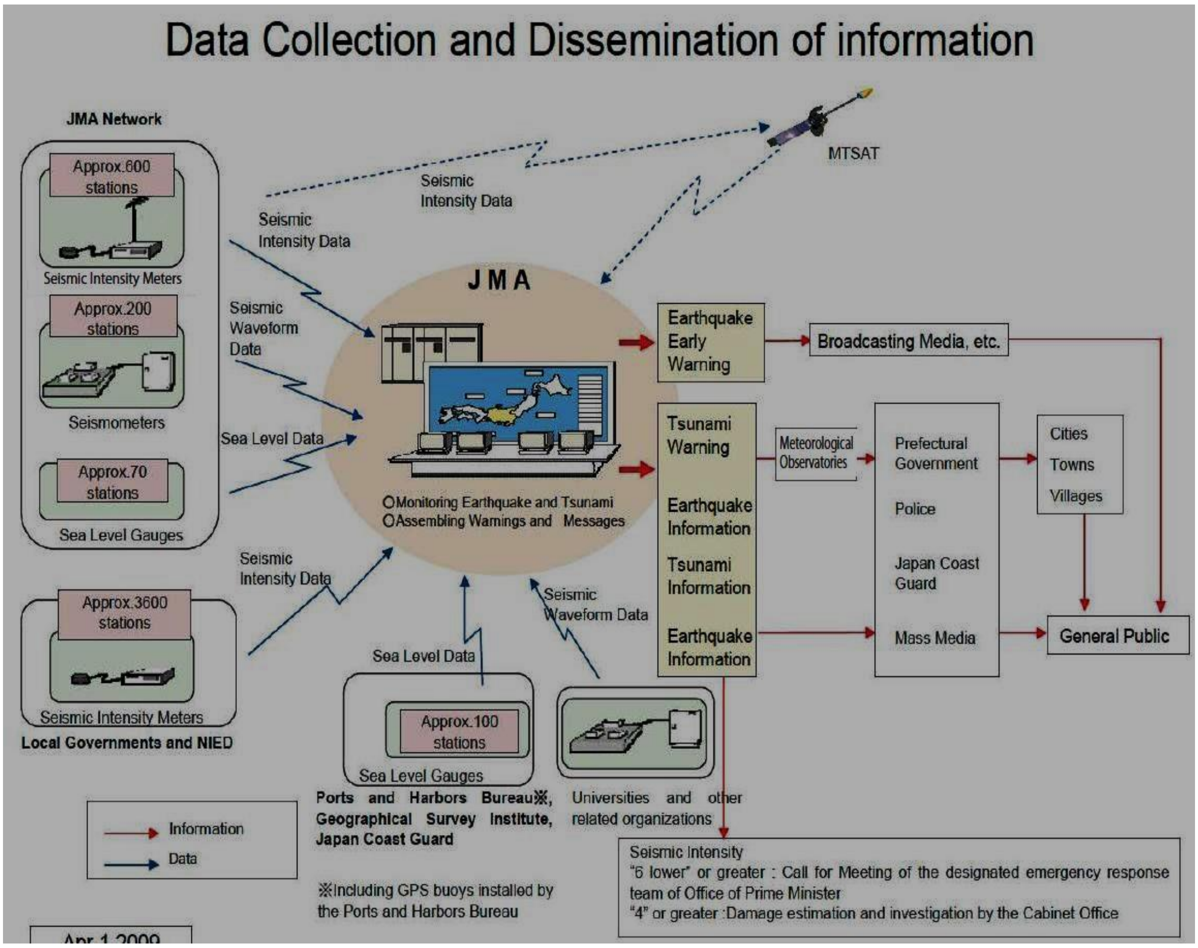


Figure 8: Data collection and Dissemination of information Source JMA

f. Earthquakes and Shaking

What is an earthquake? When people feel the ground shake, they exclaim, "It's an earthquake!" Strictly speaking, what they are feeling is ground motion caused by an earthquake. As a technical term, ground motion is used to distinguish this movement from the earthquake itself. An earthquake is a destructive slip movement inside a rock plate deep under the ground. We call the plane of this movement a fault, and the point at which a destructive slip movement starts is called the hypocenter.

Such destructive slip movements cause vibration that propagates in every direction. Since vibration travels in a wave formation, its movement is called a seismic wave. When the vibration reaches the ground surface, people become aware of earthquake motion. Thus, not all places on the surface of the ground shake at the same time. Locations closer to the hypocenter shake first, while distant areas shake later.

g. Earthquakes around Japan

The boundaries of plates covering the surface of the Earth are classified into three types: convergent, divergent, and transform types. Convergent boundaries occur where one plate subducts underneath another plate with density lower than the subducting plate or collides with another plate in the case that both plates are composed of continental material. Continental plates cannot dive into the mantle because their densities are lower than that of the mantle.
Divergent boundaries occur where new lithosphere (plate) is produced and plates move away from each other at spreading ridges.
Transform boundaries occur where one plate laterally slides past another, displacing spreading ridge. As an oceanic plate subducts underneath another plate at a convergent boundary, such area is called a subduction zone. The Japanese Islands are situated in a subduction zone in the northwestern margin of the Pacific Ocean where the Pacific Plate and Philippine Sea Plate subducting (the North American Plate and the Eurasian Plate) several centimeters annually. These plate movements cause forces to act in various directions around the country, which is the reason behind the extremely high seismic activity in the area. Around Japan, therefore, oceanic plates subduct beneath continental plates. These continental plates are dragged down as a result, and strain energy is accumulated. When this strain exceeds a certain level, it causes the continental plates to jump up, and tremors known as interplate earthquakes occur. Conversely, tremors generated by strain forces within a plate are called intraplate earthquakes. They occur in subducting plates and shallow underground areas of continental plates. Compared to interpolate earthquakes, intraplate earthquake occurring in shallow underground areas are relatively small, but can cause serious damage if they occur directly below populous areas.

h. Japans scale

The JMA scale describes the degree of shaking at a point on the Earth's surface, and is analogous to the Mercalli intensity scale. The intensity of an earthquake is not totally determined by its magnitude, and varies from place to place; for example, a quake may be described as "shindo 4 in Tokyo, shindo 3 in Yokohama, shindo 2 in Shizuoka". It is measured in units of ***shindo*** (震度, seismic intensity, lit. "Degree of shaking"). Japan experiences approximately 400 earthquakes every day, although the vast majority are *shindo scale* "0" or

less and detectable only using specialist apparatus. The Japan Meteorological Agency (JMA) first assigned a four-stage *Shindo* in 1884, with the levels: 微 (faint), 弱 (weak), 強 (strong), and 烈 (violent).
In 1898 this scale was changed to a numerical system, assigning earthquakes levels 0–7.
In 1908, the levels on this scale were given descriptions, and earthquakes were assigned levels based on their perceived effect on people. This scale was widely used during the Meiji period, and revised during the Shōwa period with the descriptions seeing an overhaul.
Following the Great Hanshin earthquake in 1995, levels 5 and 6 were divided in two, giving a total of 10 levels of earthquake: 0–4, weak / strong 5, weak / strong 6 and 7. The *Shindo* scale has been used in Japan from 1996 without change.

i. **Seismic Intensity and Magnitude**

Seismic intensity and magnitude are easily confused because both have similar values. Seismic intensity describes the scale of the ground motion at a particular location. It varies with the distance from the epicenter and the surface geology at each point. JMA s seismic intensity scale has 10 degrees (0 (imperceptible), 1, 2, 3, 4, 5-lower, 5-upper, 6-lower, 6-upper, 7). Magnitude is a numerical value that represents the scale of a fault slip underground. Large earthquakes have high magnitude.

Chapter II – Early Warning Systems

2.1 Early Warning System in Sri Lanka

Early warning mechanism in Disaster Management is a combination of tools and processes embedded within institutional structures, coordinated by national and international agencies. Whether it is focusing on one particular hazard or many, the mechanism comprises knowledge of the risk, a technical monitoring and warning.

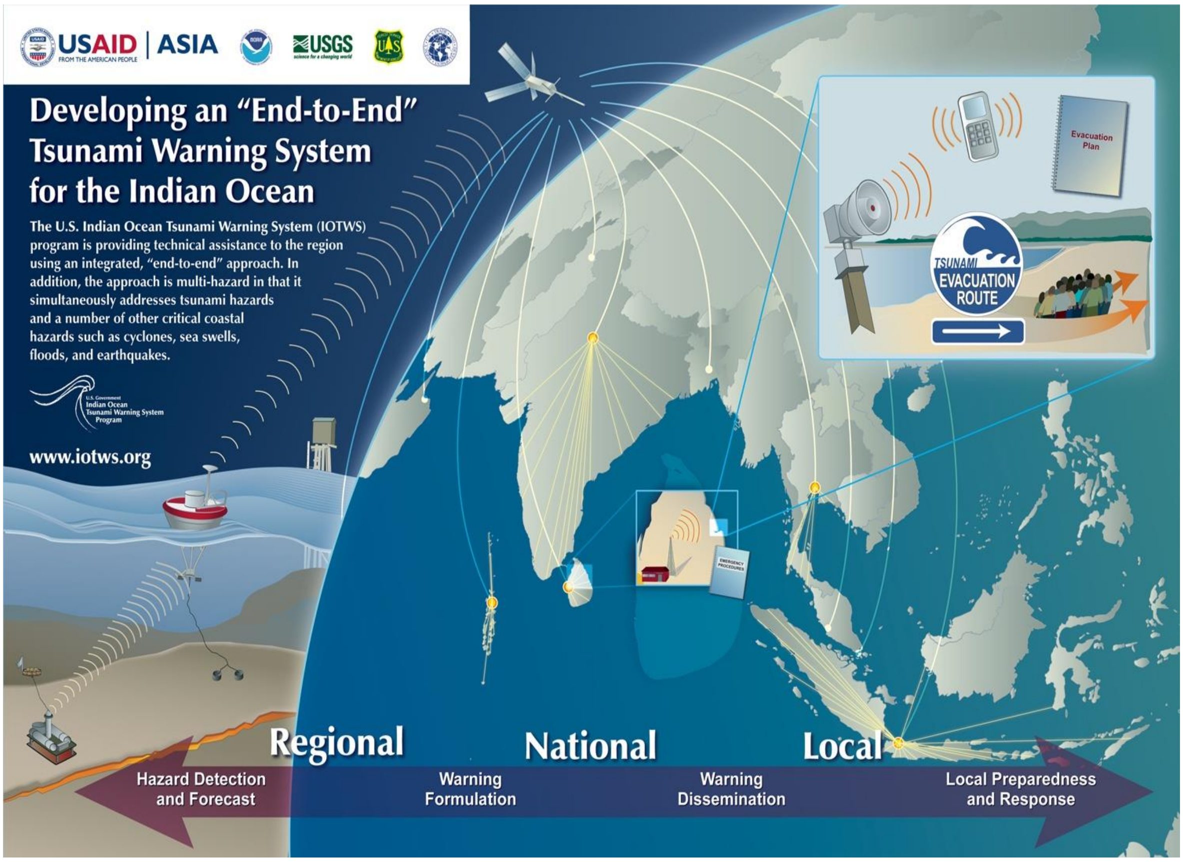


Figure 9: Indian Ocean Regional Early Warning Mechanism

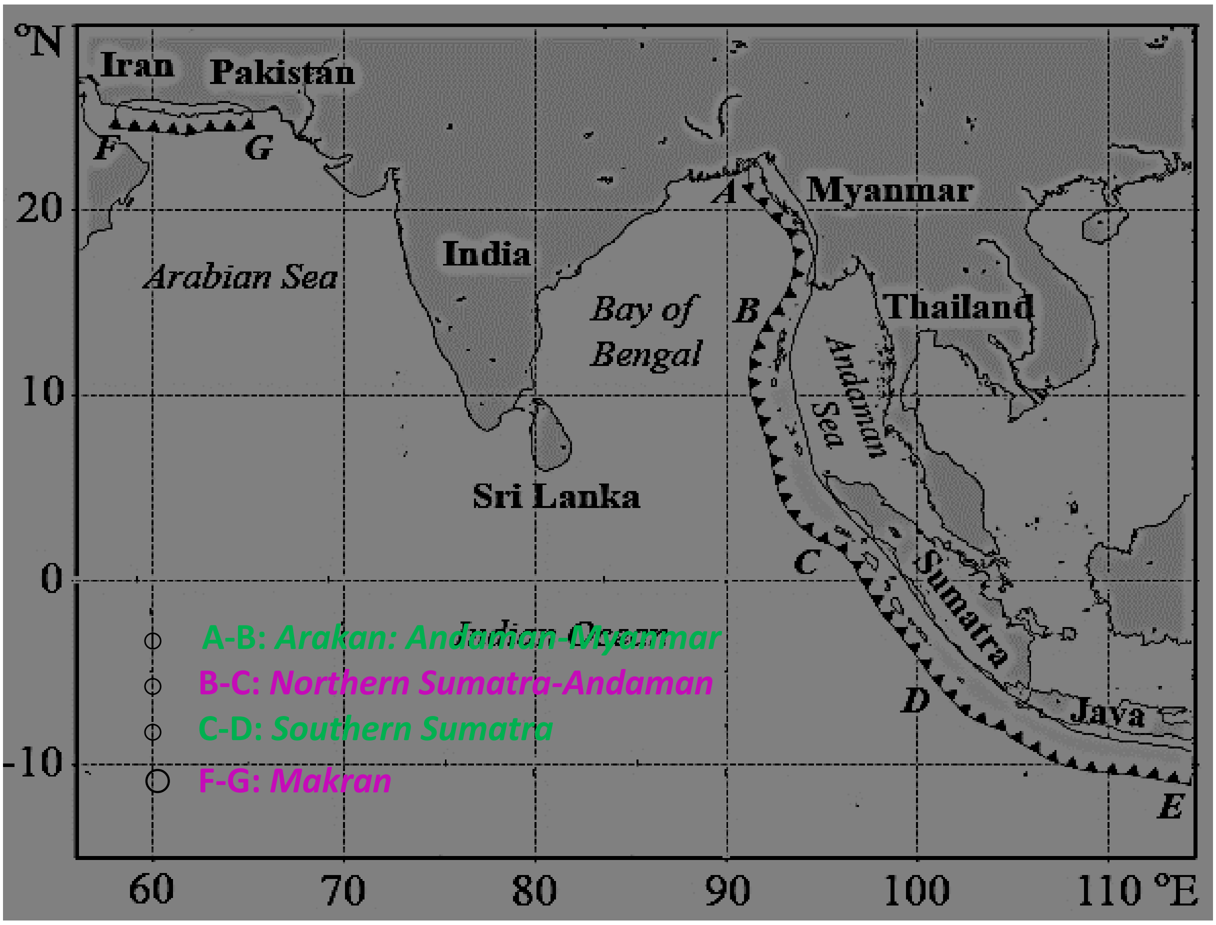


Figure 10: Two subduction zones which can generate Tsunami to Sri Lanka

Service, dissemination of meaningful warnings to vulnerable communities and public awareness and preparedness to act.

Warning services lie at the core of these systems, which will be a main task of technical agencies which are mandated on various hazards having a sound scientific basis for predicting and forecasting, and the capability to run reliably 24 hours a day.

DMC will be the focal point responsible for coordinating early warning, along with the relevant technical agencies and Technical Committees, its dissemination and for ensuring last mile dissemination. The Emergency Operations Centre of the DMC will be in constant coordination with all technical agencies responsible for natural and man-made hazards and in instances of any imminent disaster it will take action to create awareness among the people at risk.

DMC has established efficient systems to receive early warning and alert messages from different national technical agencies like Meteorological department, Irrigation Department, NARA, Geological survey and Mines Beauro etc.

a. Mandated Technical Agencies on different hazards

For the under mentioned disasters the following responsible technical agencies are mandated to provide official early warning messages to the DMC.

Disaster	Responsible Technical Agencies
(*a*) Landslide	National Building Research Organization (NBRO)
(*b*) Cyclone	Department of Meteorology
(*c*) Flood	Department of Irrigation (DOI) / Mahaweli Authority/Agrarian Services Dept./CEB/ NWSDB
(*d*) Drought	DOI, Dept. of Meteorology, Dept. of Agriculture, Mahaweli Authority
(*e*) Industrial hazard	Central Environmental Authority (CEA), NACWC
(*f*) Tsunami (seismic wave)	Dept. of Meteorology
(*g*) Earthquake	Geological Survey & Mines Bureau (GSMB)
(*h*) Air hazard Aircraft Accidents	Met. Dept., CEA Airport and Aviation Authority
(*i*) Maritime hazard	Marine Environment Protection Authority (MEPA)
(*j*) Fire	Local Authority (Fire Brigade), Police
(*k*) Epidemic	Ministry of Health
(*l*) Explosion	Ministry of Defense, Police
(*m*) Air raids	Sri Lanka Air-Force
(*n*) Civil or internal strife	Ministry of Defense, Police
(*o*) Chemical accident (Land and Sea)	Ministry of Industries, CEA, BoI, NACWC, Ministry of Defence
(*p*) Radiological emergency	Atomic Energy Authority
(*q*) Oil spills including inland & marine oil spills	MEPA , Ministry of Defence
(*r*) Nuclear disaster	Atomic Energy Authority
(*s*) Forest fire	Forest Department
(*t*) Coastal erosion	Coast Conservation & Coastal Resource Management Department (CC&CRMD)
(*u*) Tornado, lightning strikes and severe thunder storms	Department of Meteorology

Table 1: Technical Agencies responsible for issue of warnings

DMC will be the main focal point responsible for coordinating early warnings. Along with the relevant technical agencies/Technical Committees. Disaster Management Centre has to ensure last mile early warning dissemination up to the grass root level. The Emergency Operations Centre of the DMC will be in constant coordination with all technical agencies responsible for natural and man-made hazards and in instances of any imminent disasters. It will take action to inform the responsible officers for onward communication to the sub-national levels and communities. DMC has established an effective early warning system for disasters – natural, technological and man-made - through the Emergency operation Centre of the DMC. Priority will be given for those disasters, such as tsunami, floods, landslides, tropical cyclones, storm/sea surges etc.

Methods of obtaining information about impending disaster events and issuing early warnings would vary from one hazard to another due to different characteristics of different hazards. With respect to local hazards such as floods and landslides, local systems already available will be strengthened. For other hazards such as earthquakes, tsunamis, adverse weather conditions and cyclones the relevant agencies will work in constant coordination with the respective regional and international warning centers.

b. Key Responsibilities of Disaster Management Center on field of Early Warning

i. Maintaining and operating Early Warning Towers and other early warning dissemination equipment.
ii. Dissemination of Early Warning Messages and ensure the receipt at remote vulnerable villagers.
iii. Co-ordination of donor assistance to strengthen capacity of technical agencies for early warning.
iv. Working out strategy and policy in the given area of activity.
v. Initiating awareness on activities related to early warning among the various agencies and public.
vi. Guiding District Disaster Management Units in coordinating and implementing warning dissemination related activities in the Province, district, Local Authority, Division, Grama Niladhari and community levels. Other Responsibilities such as establish coordination with the local technical agencies responsible for forecasting different hazards,
vii. Establish a reliable communication system (telephones, radio communication etc.) from technical agencies to the Emergency operating Centre (EOC) and to Provincial / District Control Rooms directly or through EOC. To ensure the redundancy by having alternative communication systems in place in case of breakdowns in the main system.
viii. Have the system established with media and ensure dissemination of information through same.
ix. Create awareness among communities and all concerned agencies on the communication system in use for early warning and what immediate actions to be taken, especially on rapid onset disasters.

Technical Institutions Responsible for Forecasting and Issuing Warning Alerts for Different Hazards; and their Roles and Responsibilities. At present in Sri Lanka, there are several agencies to handle issues related to different hazards / disasters mentioned above. For most of the disasters, there is a government institution legally mandated to monitor the disasters which fall within their expertise. For example, Department of Meteorology is responsible for weather related disasters such as tropical cyclones and tsunami, while Irrigation Department is responsible for river floods. The present system of communication from national level to district / divisional / local authority / Grama Niladhari levels or other specific identified locations is mainly through the Police and military communication systems, radio communication, multi-hazard early warning towers, media and the normal telephone systems. Alternative countrywide communication systems already been established and with these improvements. DMC ensure that there will be a mechanism to inform the vulnerable communities immediately. These include the Nation-wide Emergency Communication System, which will be used to provide information on impending disasters, Inundated areas, closure of roads, safe areas etc.

Early warning messages are based on different stages which include **"Alert, Warning, Evacuation order, Withdrawals and Stand down"** as defined below.

I. **Alert:** Initial messages to the vulnerable communities /relevant authorities - Potential of a disaster.
II. **Warning:** A message to warn vulnerable communities of impending disasters to take appropriate action.
III. **Evacuation order:** Order to the vulnerable communities to evacuate to a safer location.
IV. **Withdrawal:** Cancellation of the warning messages.
V. **Stand down**: Once the threat is over, communities are informed to return to normalcy.

A comprehensive Early Warning (EW) system is established for effective issuing of EW of an impending disaster at national and sub-national levels down to the last mile where vulnerable communities are. Dissemination of warning from national level to the grassroots level is divided into four layers, namely, National, District, Divisional and GN Level. The Emergency Operation Center (EOC) of the DMC receives the EW message from International and Regional Technical Agencies. A national level EW message is disseminated to the emergency response committees and their responsibility is to pass the messages to their own organizations. District level EW is disseminated through District Disaster Management Centre Units (DDMCU) to the District Secretariat and stakeholder agencies and also to the political authority. Divisional level EW messages are disseminated to the divisional secretariat from DDMCUs. Divisional secretariat will disseminate the message to political authority, S & R teams, Police and district stakeholders. At the same time that the EW is disseminated to the local authorities they will pass the message to the vulnerable community.

GN level EW message is disseminated to the vulnerable community by last mile communication tools. According to the EW framework, when there is an impending disaster, the technical agency responsible for the given hazard determines the scale of the disaster and the decision is conveyed to the Ministry of Disaster Management and the Emergency Operation Centre of the Disaster Management Centre. The technical agency may receive hazard alerts from its own in-country monitoring facilities/ mechanisms or from regional and international EW agencies. The vulnerable community itself could also be a source of information to the technical agency regarding an impending disaster. The technical agency or the first respondent is different for different hazards.

c. Setting the Boundary

Early warning systems alone do not prevent hazards turning into disasters. Early action is essential. Early action is more wide-ranging than emergency responses, covering a range of timescales depending on the specific hazard.

The threshold levels of various technical agencies are described here.

(i) **Tsunami:** The lower boundary can be identified as the time at which the earthquake occurred.

(ii) **Flood:** Time at which the water level reaches the flood level in rivers or reservoirs declared by relevant identified technical agencies.

(iii) **Landslide**: Time at which the rainfall received reaches the saturation level. (Refer Annexed NBRO threshold level). There are specific values to be calculated. Landslide in Sri Lanka is triggered slowly by rainfall. Therefore, it is necessary to calculate the level of rainfall in deciding on the issue of an alert.

(iv) **Cyclone:** Alert level of a cyclone can be defined well in advance by predicting the expected path of the cyclone. More often the boundary for alert is set 72 hours before the cyclone enters into Sri Lankan coast.

(v) **Drought:** Slow on-set; duration may vary depending on the terrain, environmental condition and geographical area, etc.

(vi) **Other hazards**: Prediction of following hazards is dependent on the event occurring and as such cannot be predicted in advance and practically it is not possible to set a definite time for activating the NEOP.

I. Industrial Hazard
II. Earthquake
III. Air Hazard
IV. Maritime hazard
V. Fire
VI. Explosion
VII. Air Raid
VIII. Civil or internal strife
IX. Chemical accident
X. Tornado / severe thunderstorm

d. Technical Advisory Committee (TAC)

The Technical advisory committee is appointed by the National Council for Disaster Management chaired by His Excellency the President. In the discharge of its functions the National Disaster Management Council consists of professionals and experts having expertise in relation to the respective functions and responsibilities as the case may be, of the Council. DMC must ensure to contact the technical advisory committees at a disaster to establish a proper chain of the early warning of the disaster. There must be separate Technical Advisory Committees to address different types of disasters.

e. Responsibilities of the District Disaster Management Coordinating Units for early warning

The District Disaster Management Coordinating Unit (DDMCU) is the district level authority which is responsible for ensuring the dissemination of early warning messages to last mile locations. DDMCU will establish volunteer committees at the ground level and ensure to equip enough early warning methods and equipment at village level locations.

f. Role of Grama Niladhari in EW dissemination

Grama Niladhari (GN) is the government officer at the village level for the early warning dissemination. With other relevant government officers GN will update the relevant committees and ensure proper early warning dissemination at the ground level.

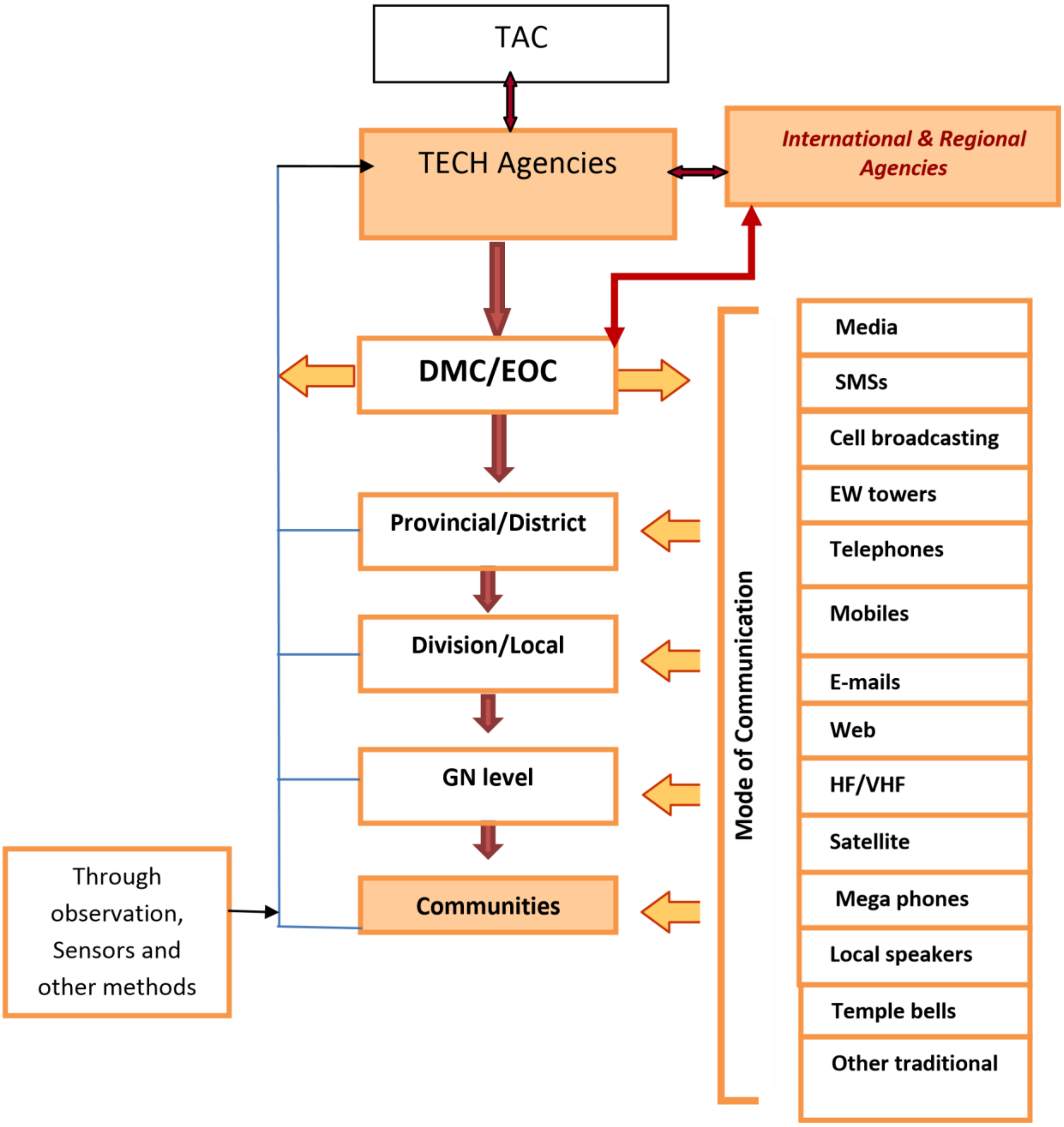


Figure 11: Method of Receiving Information and Dissemination

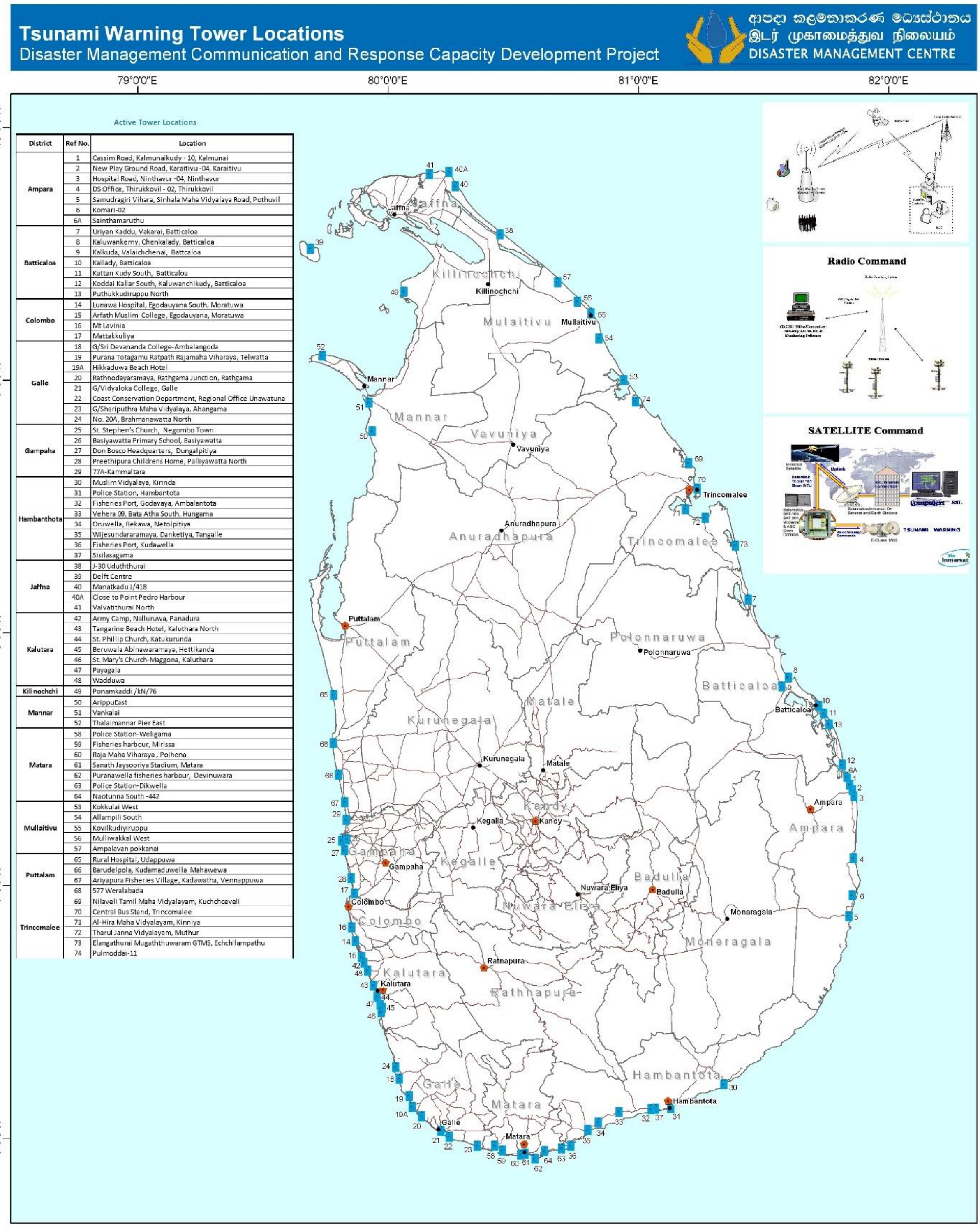
Each organization will ensure and confirm the delivery of early warning messages up to the last mile unit. DMC will confirm the proper functioning of the early warning system and ensure the reception of the warning up to the grass root level.

There are several Early Warning methods were integrated with disaster early warning network from National level to grass root level in Sri Lanka.

g. National Level and District Level Early Warning Systems

- **Early Warning Towers**. – 77 numbers of early warning towers have been established in the costal belt of Sri Lanka science 2009. Impending cyclones, tsunamis disasters situation can be disseminated through this towers within 5 to 10 minutes of period to the vulnerable communities in the costal belt. There are two ways of operate the towers which are by satellite and the VHF (Very High Frequency) communication technology. Towers were established base on the criteria which can be eliminated as risk of costal belt to the tsunami disaster, population distribution and density of the area, Vulnerability of the area and the development concern. Prerecorded messages with the siren and live voice can be disseminate to more than one kilometer distance from the base. It is also depending on the climatic conditions and the weather. National Disaster Management Center has been operating this system when it is needed and also District Disaster Management Units can operate by manually. In general, there are four messages used to deliver in the field of early warning to the public in any kind of disaster situation such as “Alert, Warning, Evacuation and Withdrawal.). This system also complies with all messages where it is recommended in disaster management concept. This is unique system for disaster early warning and no one can say where and what time to be disaster happened in Sri Lanka. However due to mono poly system, rusting of tower and maintenance cost would be main critical constrain for continue this system.

Figure 12: Early warning tower in Trincomalee district in Sri Lanka.



District	Ref No.	Location
Ampara	1	Cassim Road, Kalmunaikudy - 10, Kalmunai
	2	New Play Ground Road, Karaitivu -04, Karaitivu
	3	Hospital Road, Ninthavur -04, Ninthavur
	4	DS Office, Thirukkovil - 02, Thirukkovil
	5	Samudragiri Vihara, Sinhala Maha Vidyalaya Road, Pothuvil
	6	Komari-02
	6A	Sainthamaruthu
Batticaloa	7	Uriyan Kaddu, Vakarai, Batticaloa
	8	Kaluwankemy, Chenkalady, Batticaloa
	9	Kalkuda, Valaichchenai, Battcaloa
	10	Kallady, Batticaloa
	11	Kattan Kudy South, Batticaloa
	12	Koddai Kallar South, Kaluwanchikudy, Batticaloa
	13	Puthukkudiruppu North
Colombo	14	Lunawa Hospital, Egodauyana South, Moratuwa
	15	Arfath Muslim College, Egodauyana, Moratuwa
	16	Mt Lavinia
	17	Mattakkuliya
Galle	18	G/Sri Devananda College-Ambalangoda
	19	Purana Totagamu Ratpath Rajamaha Viharaya, Telwatta
	19A	Hikkaduwa Beach Hotel
	20	Rathnodayaramaya, Rathgama Junction, Rathgama
	21	G/Vidyaloka College, Galle
	22	Coast Conservation Department, Regional Office Unawatuna
	23	G/Shariputhra Maha Vidyalaya, Ahangama
	24	No. 20A, Brahmanawatta North
Gampaha	25	St. Stephen's Church, Negombo Town
	26	Basiyawatta Primary School, Basiyawatta
	27	Don Bosco Headquarters, Dungalpitiya
	28	Preethipura Childrens Home, Palliyawatta North
	29	77A-Kammaltara
Hambanthota	30	Muslim Vidyalaya, Kirinda
	31	Police Station, Hambantota
	32	Fisheries Port, Godavaya, Ambalantota
	33	Vehera 09, Bata Atha South, Hungama
	34	Oruwella, Rekawa, Netolpitiya
	35	Wijesundararamaya, Danketiya, Tangalle
	36	Fisheries Port, Kudawella
	37	Sisilasagama
Jaffna	38	J-30 Uduththurai
	39	Delft Centre
	40	Manatkadu J/418
	40A	Close to Point Pedro Harbour
	41	Valvatithurai North
Kalutara	42	Army Camp, Nalluruwa, Panadura
	43	Tangarine Beach Hotel, Kaluthara North
	44	St. Phillip Church, Katukurunda
	45	Beruwala Abinawaramaya, Hettikanda
	46	St. Mary's Church-Maggona, Kaluthara
	47	Payagala
	48	Wadduwa
Kilinochchi	49	Ponamkaddi /kN/76
Mannar	50	ArippuEast
	51	Vankalai
	52	Thalaimannar Pier East
Matara	58	Police Station-Weligama
	59	Fisheries harbour, Mirissa
	60	Raja Maha Viharaya , Polhena
	61	Sanath Jaysooriya Stadium, Matara
	62	Puranawella fisheries harbour, Devinuwara
	63	Police Station-Dikwella
	64	Naotunna South -442
Mullaitivu	53	Kokkulai West
	54	Allampili South
	55	Kovilkudiyiruppu
	56	Mulliwakkal West
	57	Ampalavan pokkanai
Puttalam	65	Rural Hospital, Udappuwa
	66	Barudelpola, Kudamaduwella Mahawewa
	67	Ariyapura Fisheries Village, Kadawatha, Vennappuwa
Trincomalee	68	577 Weralabada
	69	Nilaveli Tamil Maha Vidyalayam, Kuchchceveli
	70	Central Bus Stand, Trincomalee
	71	Al-Hira Maha Vidyalayam, Kinniya
	72	Tharul Janna Vidyalayam, Muthur
	73	Elangathurai Mugaththuwaram GTMS, Echchilampathu
	74	Pulmoddai-11

Figure 13: Military EW dissemination Mechanism.

- **Police & Military Communication system -** DMC has direct coordination with military and police to disseminate the early warning messages to vulnerable communities. Military and Police posts are located in many areas in the entire country. DMC must ensure the communication method and the accuracy of the early warning messages. Military and Police have their own communication systems which can access vulnerable communities and they can direct these communities to safe locations at ground level.

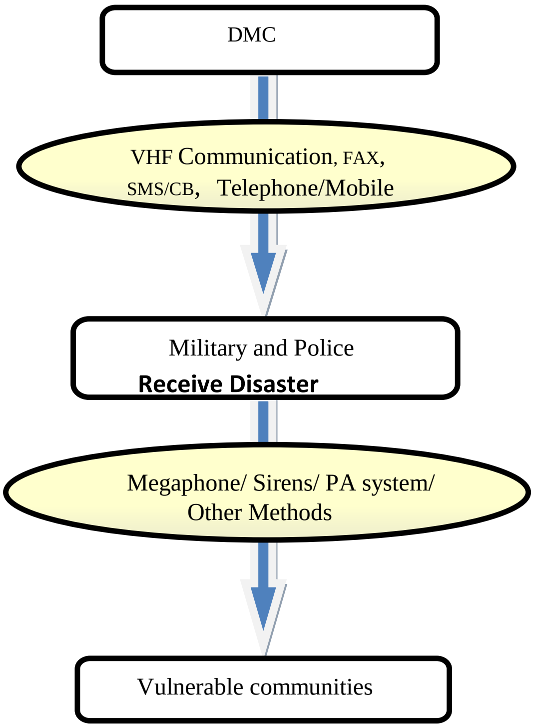


Figure 14: Military and Police in EW dissemination

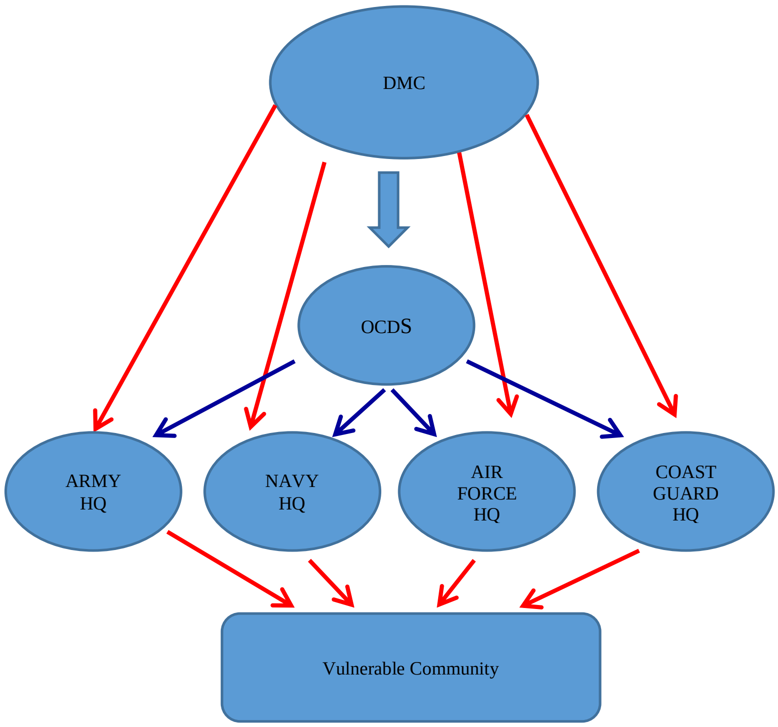


Figure15: Military and Police in EW dissemination

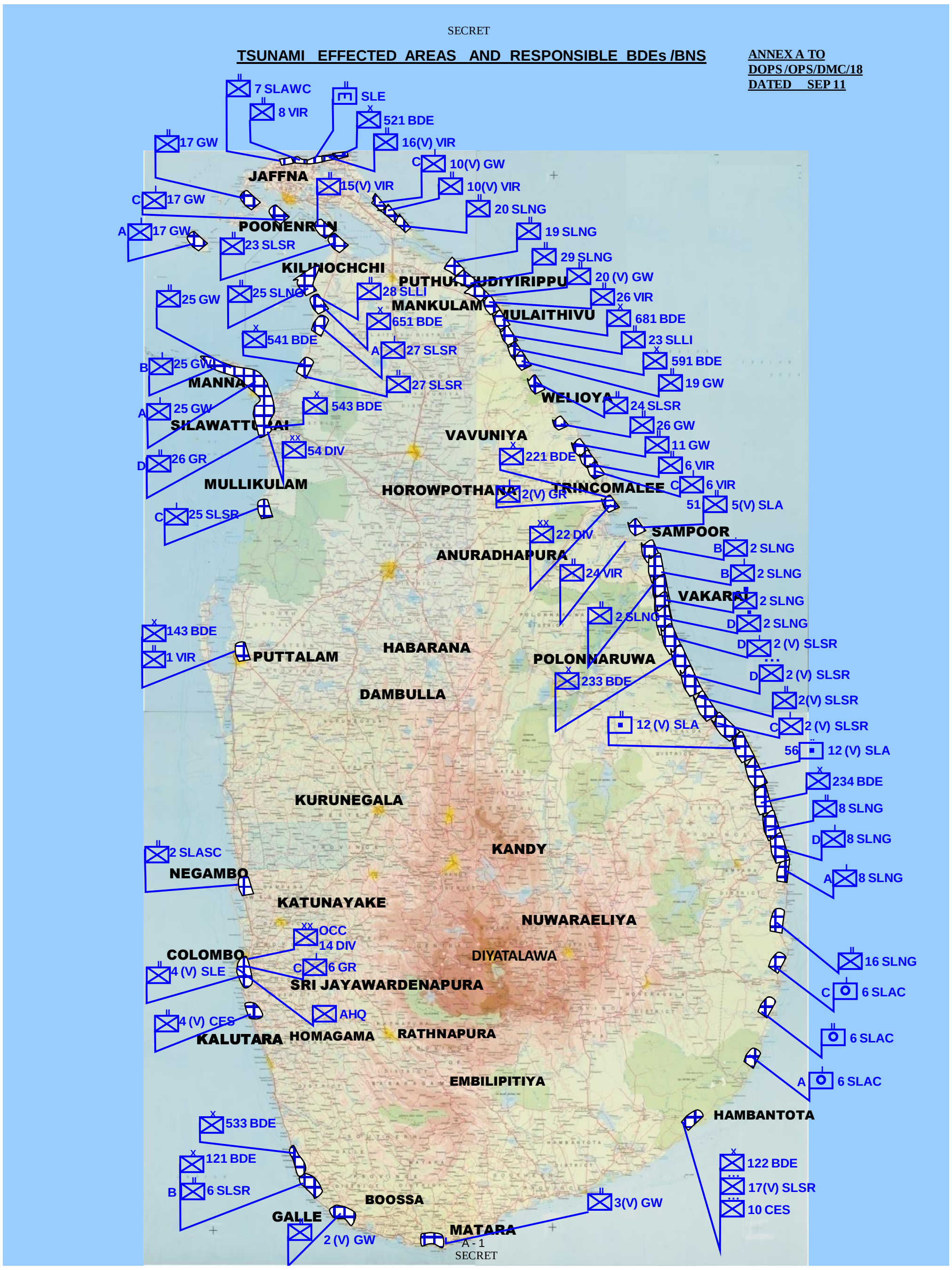


Figure 16: Army in EW dissemination

- **Cell Broadcast and SMS -** The Disaster Management Centre (DMC), together with Dialog and other partners launched Disaster Emergency Warning Network (DEWN) – Sri Lanka's first mass alert early warning system on 30th January 2009 after completing a successful pilot period. The Disaster and Emergency Warning Network (DEWN) uses GSM communication technologies and devices, and transmits alerts through the GSM network. It can be used to issue customized alerts to selected recipients instantaneously, and is compliant with the internationally accepted alerting protocol – CAP.The Emergency Operation Centre (EOC) of the Disaster Management Centre has been given access to the secure DEWN alerting interface. When information is received by the DMC, the information is verified, and customized alerts (with message text and recipients specified) are issued. Messages can be received by mobile phones or the specially developed DEWN Alarm devices. In a potential disaster scenario, DEWN will be used to first alert the emergency personnel on their individual phones and public alerts will issued only when a threat is adequately verified. It has developed special phone software for Java/Symbian capable (smart) phones that causes the phone to rings continuously until acknowledged and displays the messages in all 3 local languages (Sinhala, English and Tamil). The software can be downloaded free. DMC District Coordinators and other Special Disaster Management members, being the first contact in each district, will be instrumented with such phones that members referred as "key contactors". 5000 key contactors are being registered in the system in different locations in the country. More than eight million customers can be received the DEWN Cell broad cast message at once. Only dialog customers can be received the CB massagers. However, there is no any restriction to SMS reception from any services providers unless otherwise not registered in the system.

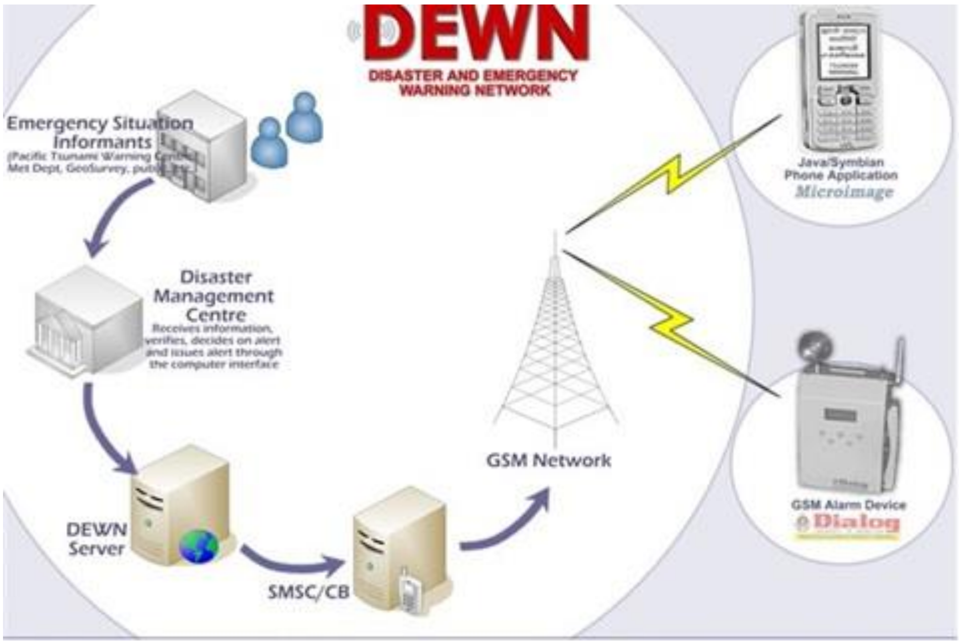


Figure 17: DEWN communication Network

- **Intra Governmental Network –** Intra government network is being facilitating to communicate the information with the disaster management stakeholders district disaster management unit by virtual privet network (VPN). This system has designed as a user friendly mechanism with three digit numbers. This system has Initially introduced by the Japan International Cooperation Agency.

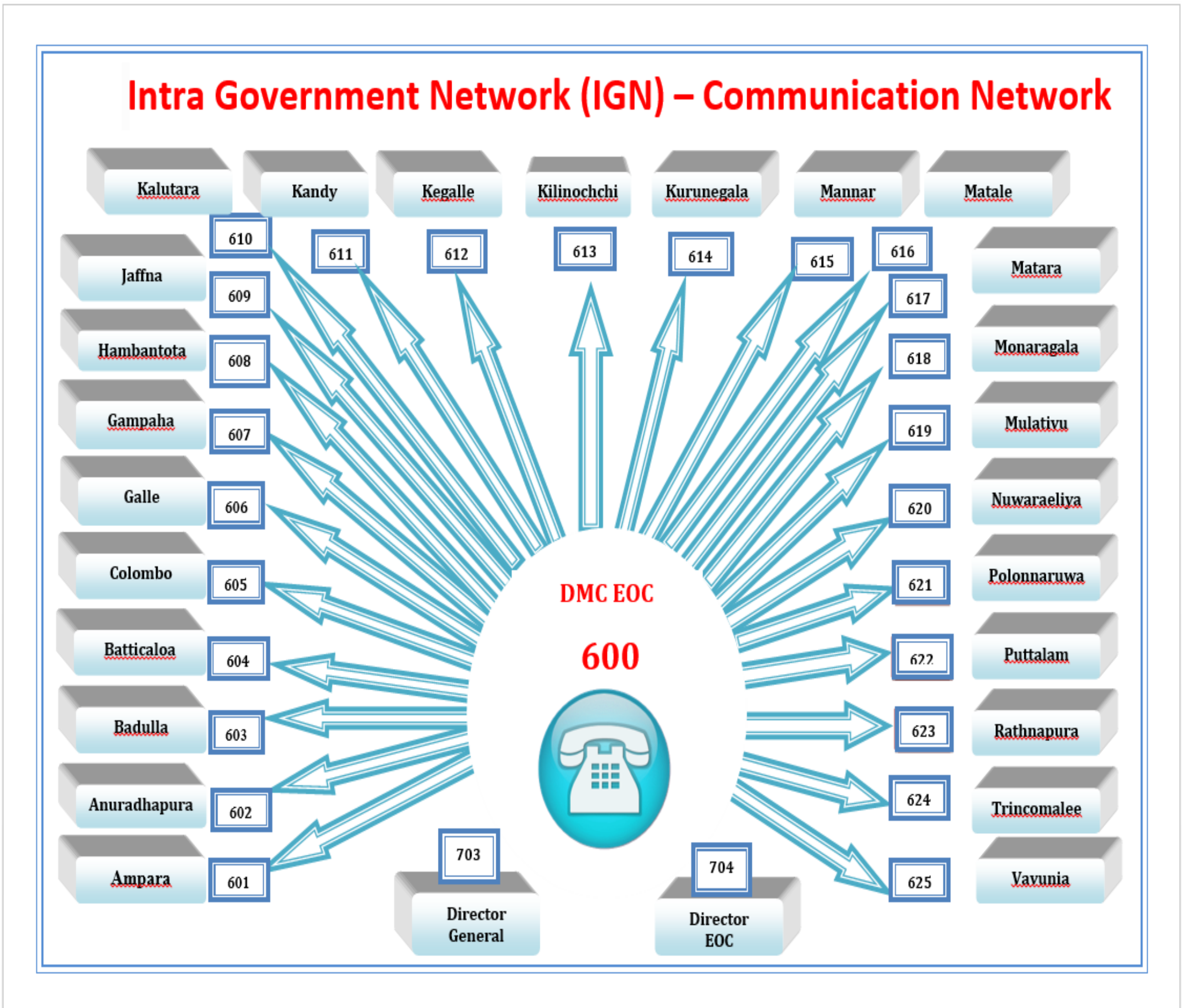


Figure 18: Intra Government Communication Network

- **Satellite Communication Network –** The innovative Thuraya GSM Solution provides added convenience for users needing to communicate outside of the GSM network range. It is used to extend GSM services to remote locations (mobile locations) with Thuraya IP as the backbone link. It gives end-users added mobility, more freedom and fewer restrictions on their communications. Thuraya GSM can enjoy the convenience of using a GSM phone in remote locations since calls are established over Thuraya's powerful mobile satellite in the packet mode. Its main function is to allow GSM roaming in remote and isolated locations where GSM services are generally not available. This thuraya network has established in the DMC head office and district level consisting with thuraya mobile and base station devices. This communication system cannot be used in ordinary time due to high cost of operation. But it is very useful at the disaster situation thus other network jammed in the country.

Figure 19: Thuraya communication Network

- **Land line telephones / CDMA –** The landline is also used to describe a connection between two or more points that consists of a dedicated physical cable, as opposed to an always-available private link that is actually implemented as a circuit in a wired switched system. This system has dedicated lines connected to the all agencies and institutes of the country such as police, fire department, hospitals, Military, etc. Deployed as a precaution in case of emergency, these can be used at any time. CDMA, which stands for *Code Division Multiple Access*, is a competing cell phone service technology to GSM. This type of phones also use to communicate with others in an emergency and ordinary time. DMC has also established the intra call network through the “ SISCO “ system.

- **Fax -** An image of a document made by electronic scanning and transmitted as data by telecommunication links is called fax. Fax is used in the ordinary an emergency situation to ensure the authentication and identity for post disaster evaluation and documentation. Most of the emergency situation this system cannot be used due to communication system jammed.

- **Radio Communication Network -** Radio is the technology of using radio waves to carry information, such as sound, by systematically modulating properties of electromagnetic energy waves transmitted through space, such as their amplitude, frequency, phase, or pulse width. When radio waves strike an electrical conductor, the oscillating fields induce an alternating current in the conductor. The information in the waves can be extracted and transformed back into its original form.

  Radio systems need a transmitter to modulate (change) some property of the energy produced to impress a signal on it, for example using amplitude modulation or angle modulation (which can be frequency modulation or phase modulation). Radio systems also need an antenna to convert electric currents into radio waves, and vice versa. An antenna can be used for both transmitting and receiving. The electrical resonance of tuned circuits in radios allow individual stations to be selected. The electromagnetic wave is intercepted by a tuned receiving antenna. A radio receiver receives its input from an antenna and converts it into a form that is usable for the consumer, such as sound, pictures, digital data, measurement values, navigational positions, etc. Radio frequencies occupy the range from a 3 kHz to 300 GHz, although commercially important uses of radio use only a small part of this spectrum.

A radio communication system sends signals by radio. The radio equipment involved in communication systems includes a transmitter and a receiver, each having an antenna and appropriate terminal equipment such as a microphone at the transmitter and a loudspeaker at the receiver in the case of a voice-communication system.

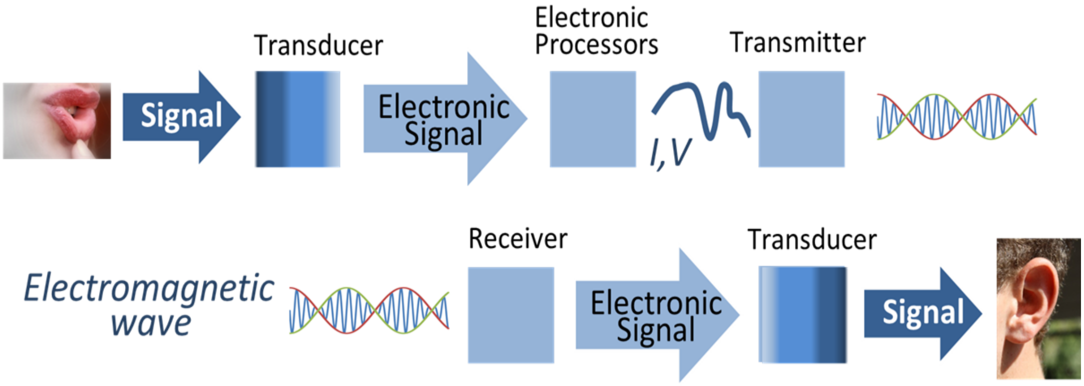


Figure 20: Electronic wave transforming technic

The radio equipment involved in communication systems includes a transmitter and a receiver, each having an antenna and appropriate terminal equipment such as a microphone at the transmitter and a loudspeaker at the receiver in the case of a voice-communication system. The power consumed in a transmitting station varies depending on the distance of communication and the transmission conditions. The power received at the receiving station is usually only a tiny fraction of the transmitter's output, since communication depends on receiving the information, not the energy, that was transmitted.

A radio communication system may send information only one way. For example, in broadcasting a single transmitter sends signals to many receivers. Two stations may take turns sending and receiving, using a single radio frequency; this is called "simplex." By using two radio frequencies, two stations may continuously and concurrently send and receive signals - this is called "duplex" operation.

Disaster Management center has a radio communication Network with 12 designated channels of VHF for short distance and HF for long distance. To activation and proper function of these system, repeater station and base stations have been established in various locations in the country. Piduruthalagala, Gongala, Panagoda ,karagahathanna, Towood, Kokawill, are the main repeater station were established. This system has been facilitated to communicate with various organizations such as media, police, military, etc and sub national levels. All the disaster management vehicles fixed with the same radio facilities to communicate with their respective headquarters. By having base station, it can communicate more than ten kilometers radius form the initiate point. Handheld set can be communicated less than five kilometers radius form the initiate point. Also DMC allocated call sign for each organization for operational prospect of view.

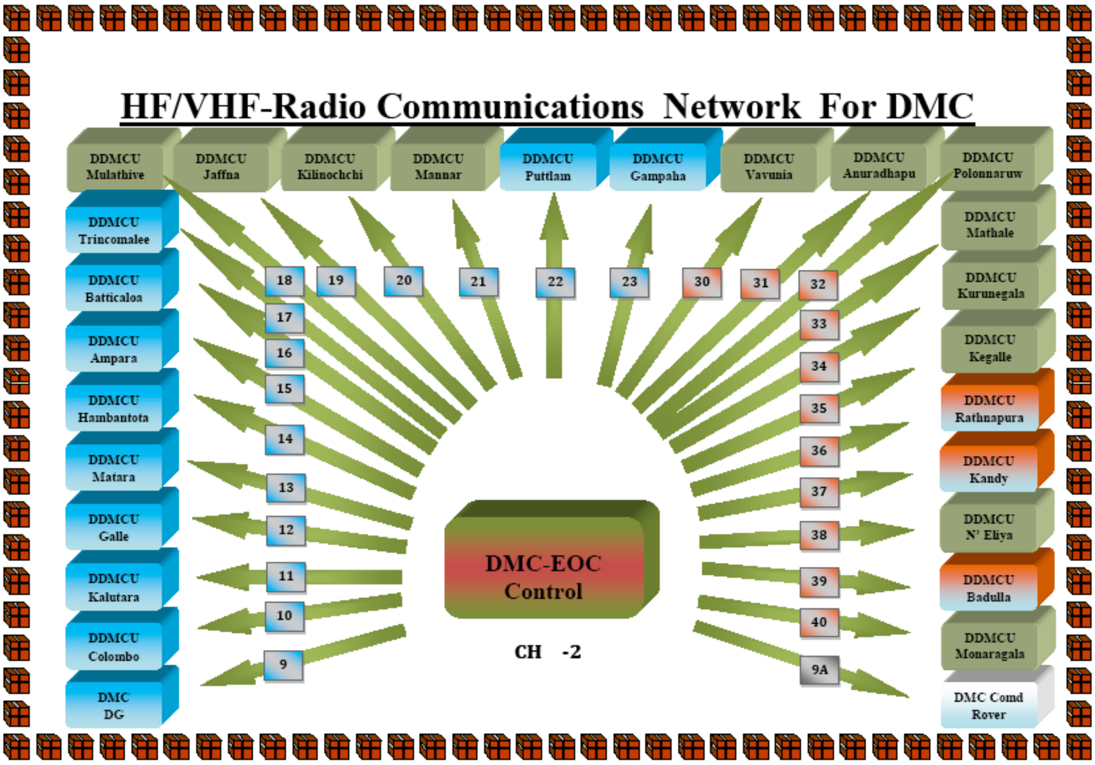


Figure 21: Thuraya communication Network

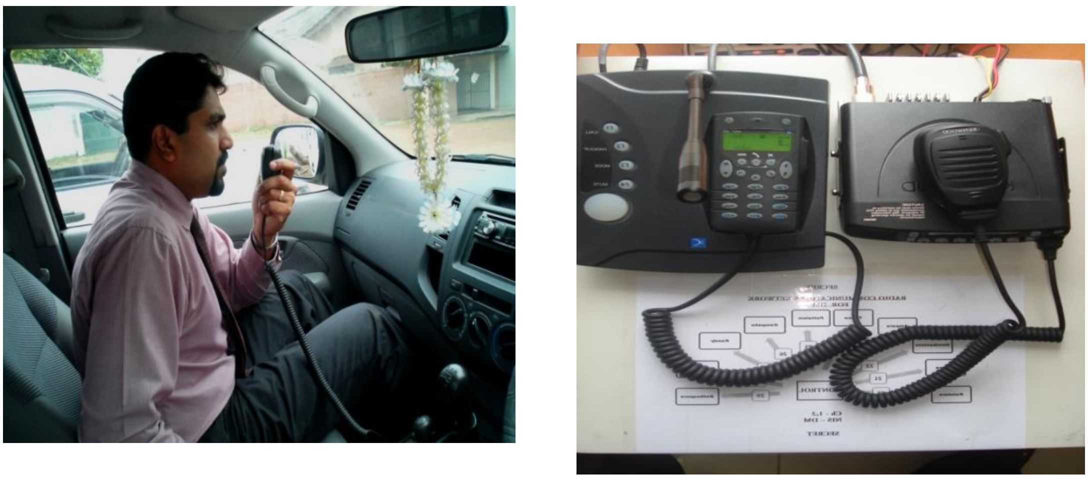


Figure 22: Radio Communication system in Vehicle

- **Mobile Network -** A cellular network is used by the mobile phone operator to achieve both coverage and capacity for their subscribers. Since almost all mobile phones use cellular technology, including GSM, CDMA, and AMPS (analog), DMC also ben used all kind of mobiles for data sharing and information sharing in round the clock. DMC already been established a mobile network within national to district level for effective communication. However, the mobile communication network has interrupted and jammed due to call traffic and there is no capacity to cater the demand of the public at a calamity. Therefore the mobile communication opportunity has only 15 to 20 minutes' window opportunity to communicate at a disaster.

- **Fisheries and Fir Brigade Radio Communication System –** Fire brigade and fisheries department have separate communication system to coordinate with responsible officers and other relevant boats. Fisheries department has HF and VHF radio communication system to communicate with multi-day boats and ships. This communication system has made an opportunities to communication at a disaster even if they are in the sea or harbor.

- **Media.** – Disaster management center has appointed a media Sparkman to release early warning information on the impending disasters. Media play a significant role in creating awareness about disasters among common masses and thus reduce disaster risks. Media plays a prominent role in Sri Lanka, covering the entire island easily through television and FM radios with more than 50 channels. National and local media channels have an edge on EWS. Their business is communication, getting the word out to the largest possible group of listeners or readers. The media also have the responsibility to relay accurate and timely information to those in need.

  During disaster situations, media should not only inform the public with timely and factual information but also advice the public about actions to be taken (e.g. evacuation, useful tips, techniques, do's and dont's, etc.) and also inform on actions being taken by authorities, aid groups and relief organizations. During an emergency, the media should be sensitive to the needs of the public in affected areas and should avoid misinforming and broadcasting unconfirmed reports that may lead to despair and panic. Reliable and timely information provided through the media which are obtained through DMC and technical agencies help people overcome unnecessary fear and fatalism during and after an emergency. Further, the DMC will organize press briefings as and when required on situational updates.

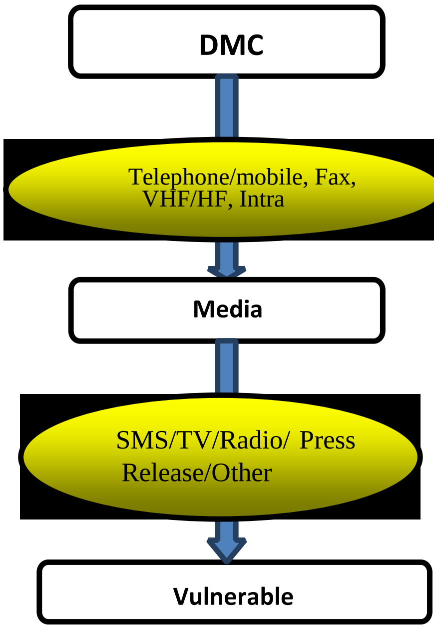


Figure 23: Role of the Media in Early Warning dissemination

- **Social Media Network –** Social media are computer-mediated technologies that allow the creating and sharing of information, ideas, career interests and other forms of expression via virtual communities and networks. The variety of stand-alone and built-in social media services currently available introduces challenges of definition. However, there are some common features. Social media use web-based technologies, desktop computers and mobile technologies (e.g., smartphones and tablet computers) to create highly interactive platforms through which individuals, communities and organizations can share, co-create, discuss, and modify user-generated content or pre-made content posted online. Social media changes the way individuals and large organizations communicate. Internet users continue to spend more time on social media sites than on any other type of site. For content contributors, the benefits of participating in social media have gone beyond simply social sharing to building reputation and bringing in career opportunities and monetary income. These changes are the focus of the Disaster early warning. Specially Facebook, twitter, Viber, Messenger, WhatsApp, Imo etc are being used to early warning in the country. Most of younger generation already been used to utilized the social media for other purpose thus it is used to receive the early warning.

- **E-mail and internet-** Electronic mail, or email, is a method of exchanging digital messages between people using digital devices such as computers, tablets and mobile phones. Email operates across computer networks, which today is primarily the internet. Disaster management center has utilized Email to pass the early warning to disaster managers which are disaster management stakeholders. Also web site use to publish the early warning before the disaster occur that can be used to people to decision making and evacuation to the safe ground.

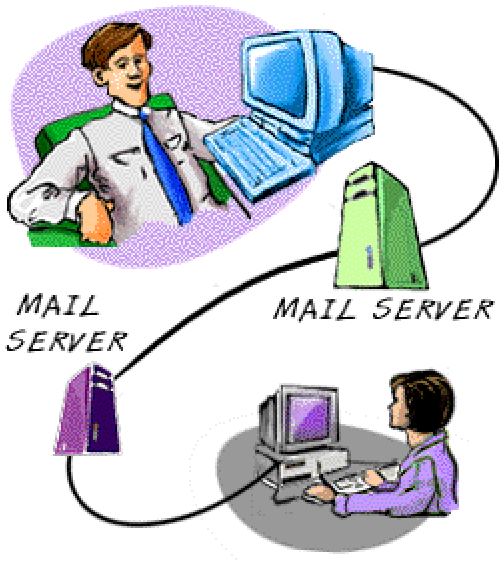


Figure 24: Use of internet to Early Warning dissemination

- **117/119 call centers -** A call centre or call center is a centralized office used for receiving or transmitting a large volume of requests by telephone. Disaster Management Center has established a call center to cater the disaster management communication while shearing the early warning to the public. 25 seated has been allocated to call center and it is working 24/7 basis.
  Also 119 short cord communication line has been allocated under the department of police in Sri Lanka. It is also help to share the early warning messages to the public.

Figure 25: 117 Call centre operation in Sri Lanka.

h. Village Level

Fallowing early warning systems are being used to warn the people in the community levels in the any impending disasters. These the systems are used base on demography, availability, usability, feasibility and acceptability of the community. However, land line telephones, towers, SMS, mobile network and media are activating same as national level. But once received the information to the respective institution, authority, or volunteers through the national disaster management center on impending disasters, the early warning mechanism will be activated. By using following any method or more than one methods, are used to inform the vulnerable communities.

- Land line telephones / CDMA
- Early Warning Towers
- SMS / Cell Broad cast
- Mobile Network
- Media
- Police Vehicles – Announcements
- NGOs and CBOs
- PA Systems/ Mega phones.
- Sirens (Hand and Electric)
- Temple and church bells
- Riders/ Push Bicycle & Motor Cycles/Messengers
- Early Warning Committees (Door to Door)
- Flags and different colour cords.
- Mosque Public Address system.
- Mouth to mouth.
- Traditional and other cultural systems

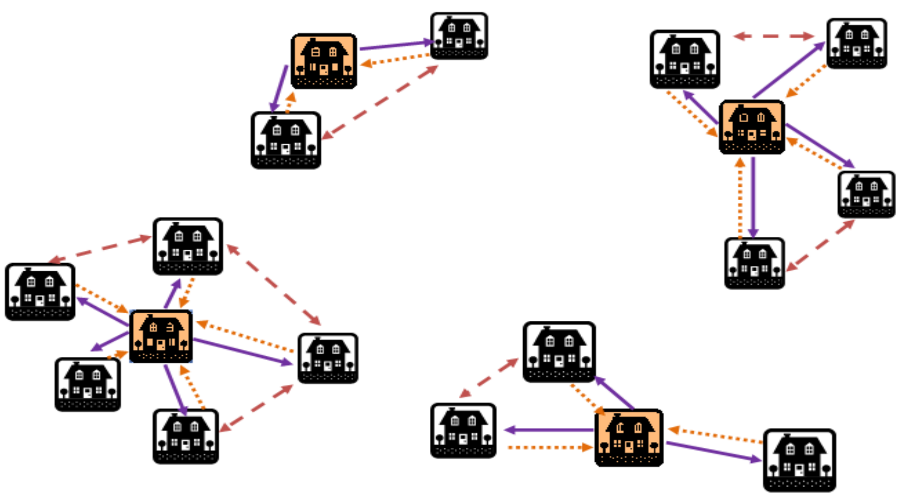


Figure 26: Community volunteers Early Warning dissemination

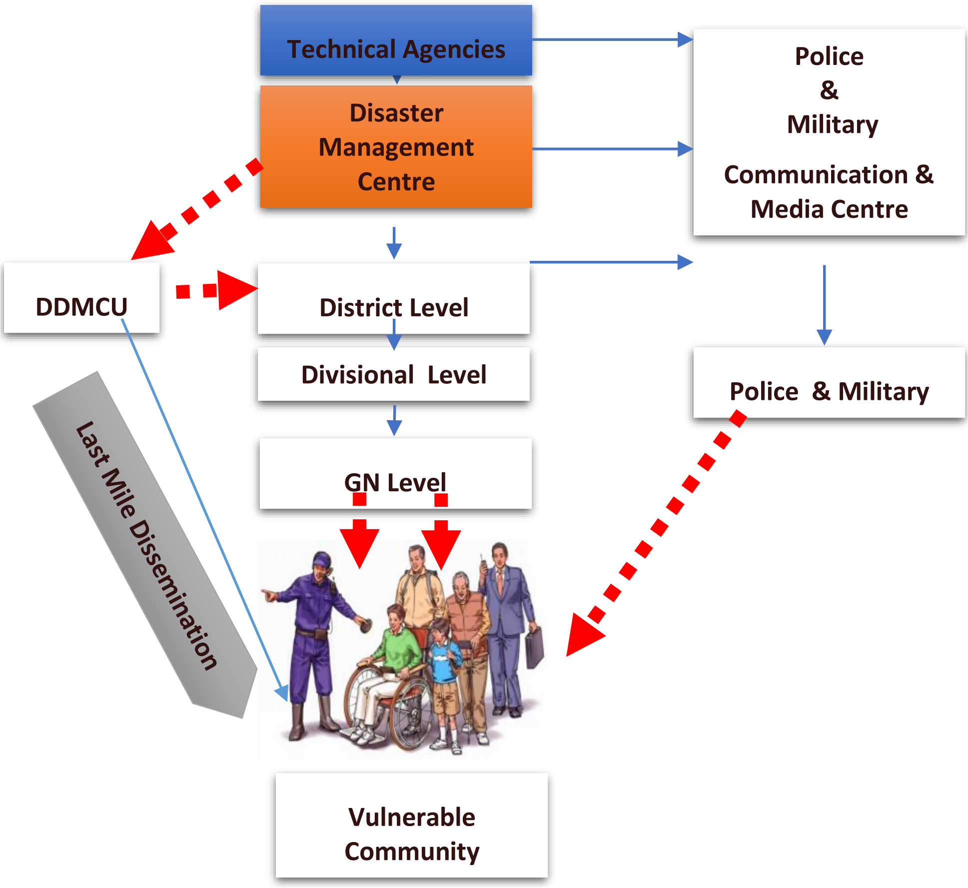


Figure 27: Last mile Early Warning dissemination

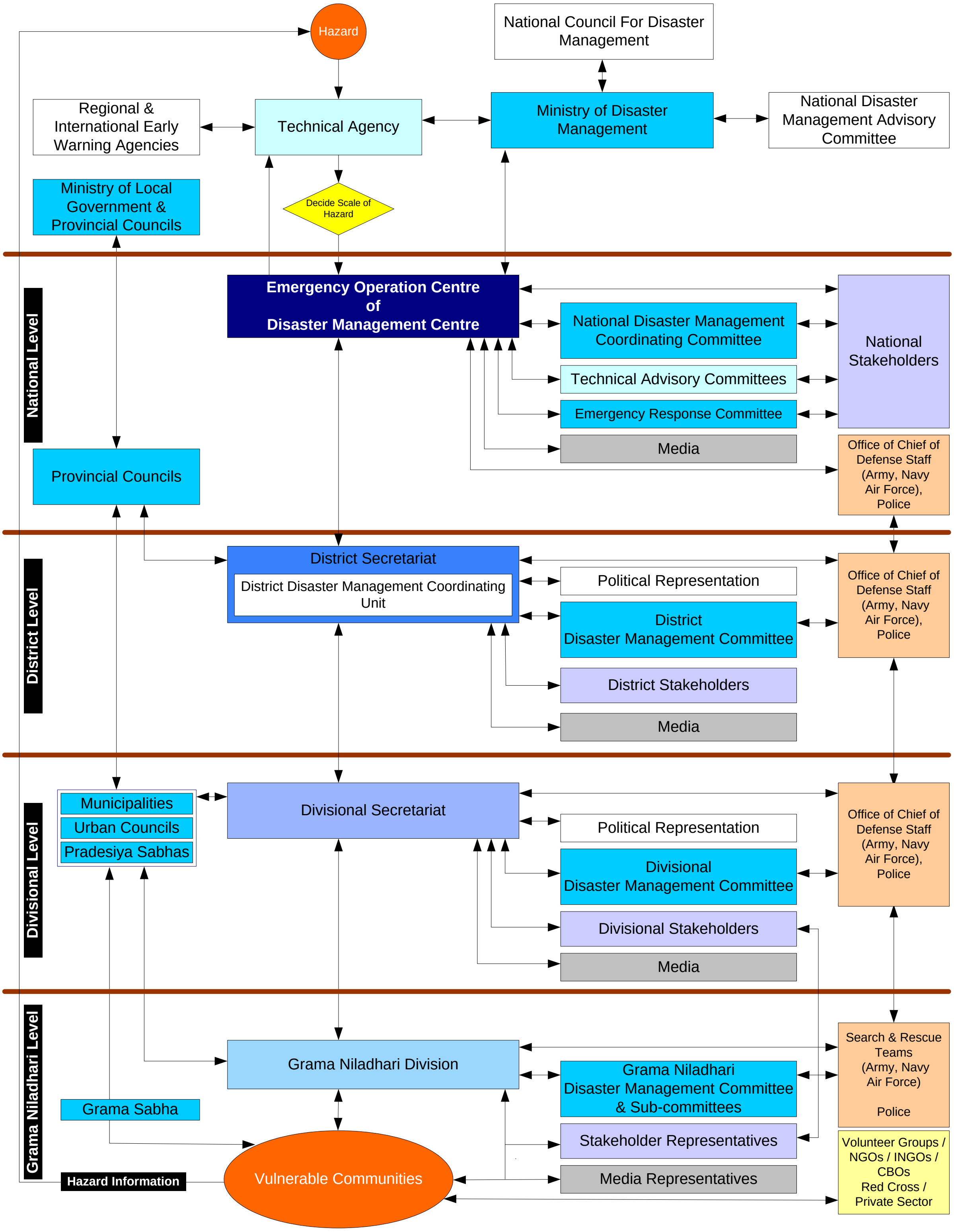


Figure28: Early Warning Coordination framework

2.2 Early Warning System in Japan

Japan Meteorological Agency (JMA) is the sole national authority responsible for issuing weather/tsunami warnings and advisories, earthquake early warning/alerts, and other disaster warning and is required to provide reliable and timely information to governmental agencies and residents for the purposes of natural disaster prevention and mitigation. Within the structural framework of Japan's central government, the JMA is placed as an extra-ministerial bureau of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). When a Heavy Rain Warning is issued.

Sediment Disaster Alerts are issued jointly by MLIT and prefectural government civil engineering bureaus when sediment-related damage caused by heavy rain is considered likely within the next few hours. JMA is also responsible for providing flood forecasting services in collaboration with central and local river management authorities. These services include flood warnings and advisories covering 407 rivers (as of March 2011) throughout the country that have been designated by these authorities as sites of potential flood disasters. Flood forecasting systems for 289 of the 407 rivers are managed jointly by JMA and the MLIT, and the other 118 are managed jointly by JMA and prefectural governments. JMA operationally monitors seismic and volcanic activity throughout the country and issues relevant warnings and information to mitigate damage caused by disasters related to earthquakes, tsunamis and volcanic eruptions. JMA began issuing volcanic warnings and volcanic forecasts for each active volcano in Japan on Dec 1, 2007 to mitigate damage from volcanic activity. Volcanic warnings are issued in relation to expected volcanic disasters, and specify the municipalities where people need to take action. Volcanic forecasts are issued for less active volcanoes or those that become so.

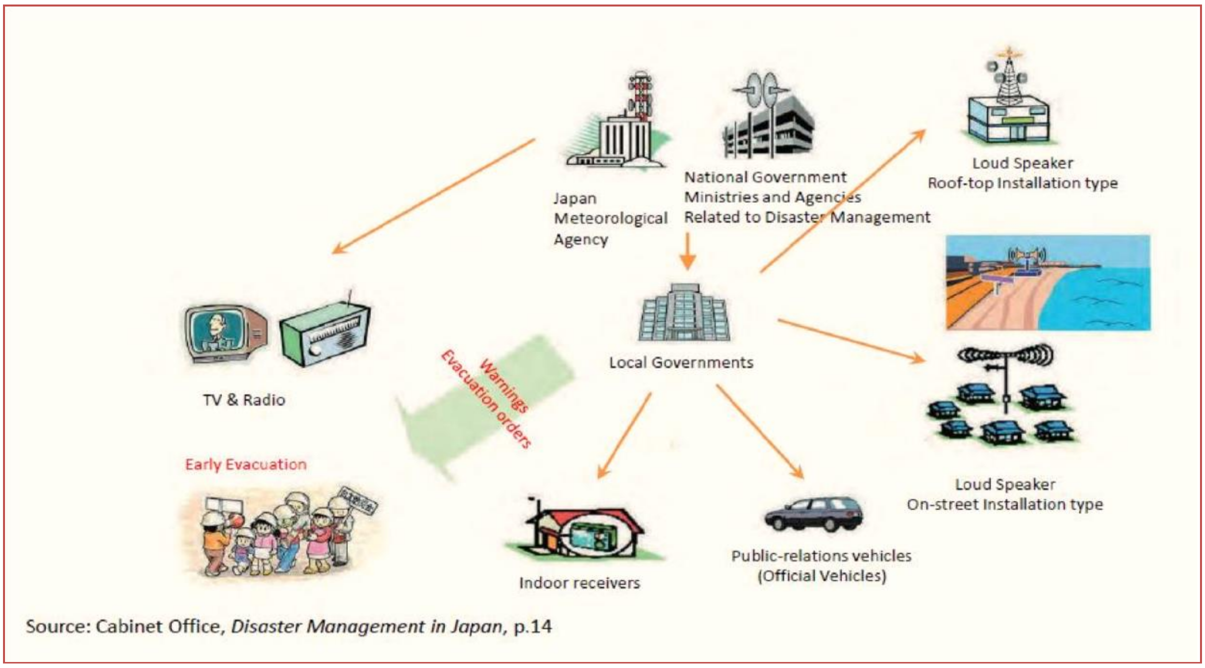


Figure 29: An Outline of EWS in Japan Source: Cabinet Office, Japan.

JMA operates the Sapporo, Sendai, Tokyo, Osaka, Fukuoka and Okinawa Regional Headquarters to observe and monitor weather and earthquakes and to issue forecasts, warnings and bulletins for these regions. The Regional Headquarters give direction to Local Meteorological Offices for the issuance and provision of information and comments on prefectural and municipal levels. The Agency operates Aviation Weather Service Centers at major airports to support the safe flow of air traffic. JMA also operates the Meteorological Research Institute, the Meteorological Satellite Center, the Agrological Observatory, the Magnetic Observatory and the Meteorological College as location to research.

a. Dissemination of Forecast and Early Warning

In order to prevent and mitigate damage caused by natural disasters and support prompt disaster prevention activities, JMA disseminates weather information and warnings via various channels to government disaster prevention agencies, local governments, the mass media and the public. For this purpose, the Agency maintains direct communication links with meteorological offices and central/local governments. Strong communication with municipal governments that play direct roles in disaster management and mitigation in affected areas is essential. Such communication is ensured via various channels for information dissemination, such as prefectural governments, NTT (Nippon Telegraph and Telephone Corporation), J-ALERT (an instant information broadcasting system introduced by the Fire and Disaster Management Agency (FDMA) and the Internet. To support prompt disaster mitigation activities by local governments, the Agency has introduced a new information provision system called the Information Network for Disaster Prevention (INDiP), which enables effective and rapid dissemination of data in both text and graphic form.

INDiP connects disaster prevention agencies and local governments with JMA headquarters via the Internet and provides detailed weather information and warnings tailored to individual municipalities. Information for maritime users is transmitted via the JMH radio facsimile broadcast service operated by JMA and fishery radio communications services. Such information is also disseminated within the framework of the Global Maritime Distress and Safety System (GMDSS), i.e. via the NAVTEX broadcast service of the Japan Coast Guard for seas in the vicinity of Japan, and via the Safety-Net broadcast service for ships in the high seas via the maritime satellite INMARSAT. Nowadays, the Internet plays a vital role for JMA in the public dissemination of a wide range of meteorological information not only on forecasts but also on historical and current observation data.

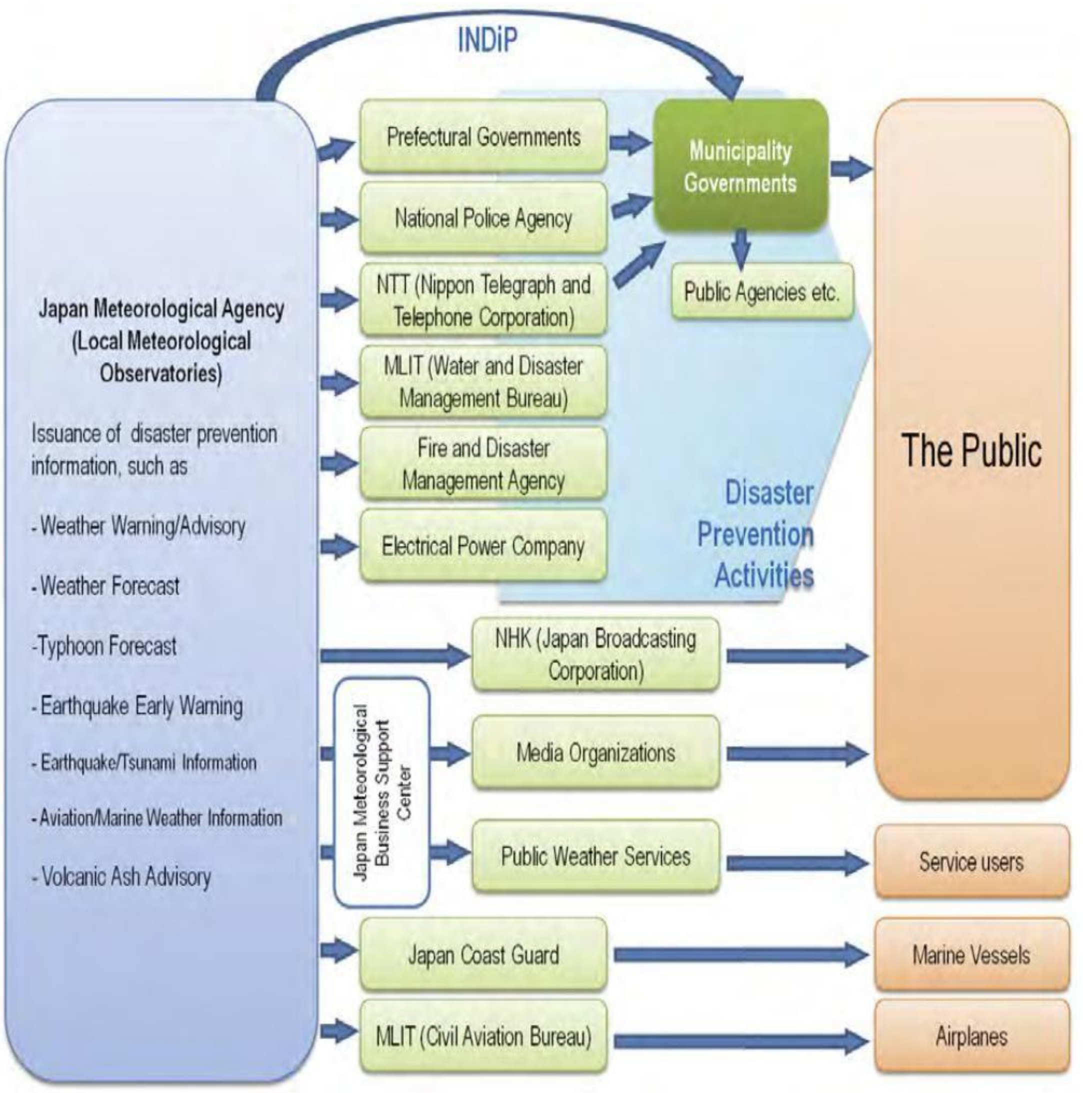


Figure30: Flow of information from JMA to the public

b. J-Alert System

J-Alert is the system to immediately transmit emergency information such as Emergency Earthquake information, tsunami warning, information of ballistic missiles, which people have no enough time to deal with, is transmitted to the municipalities by using satellite (via the Fire and Disaster Management Agency, the Cabinet Secretariat, and JMA). It became operational on 09 February 2007 and on 01 October 2007 started sending the emergency earthquake information. As of first March 2010, 344 municipalities have introduced this system. Among them, automatic activation system of radio broadcasting and community FM has been introduced to 282 municipalities.

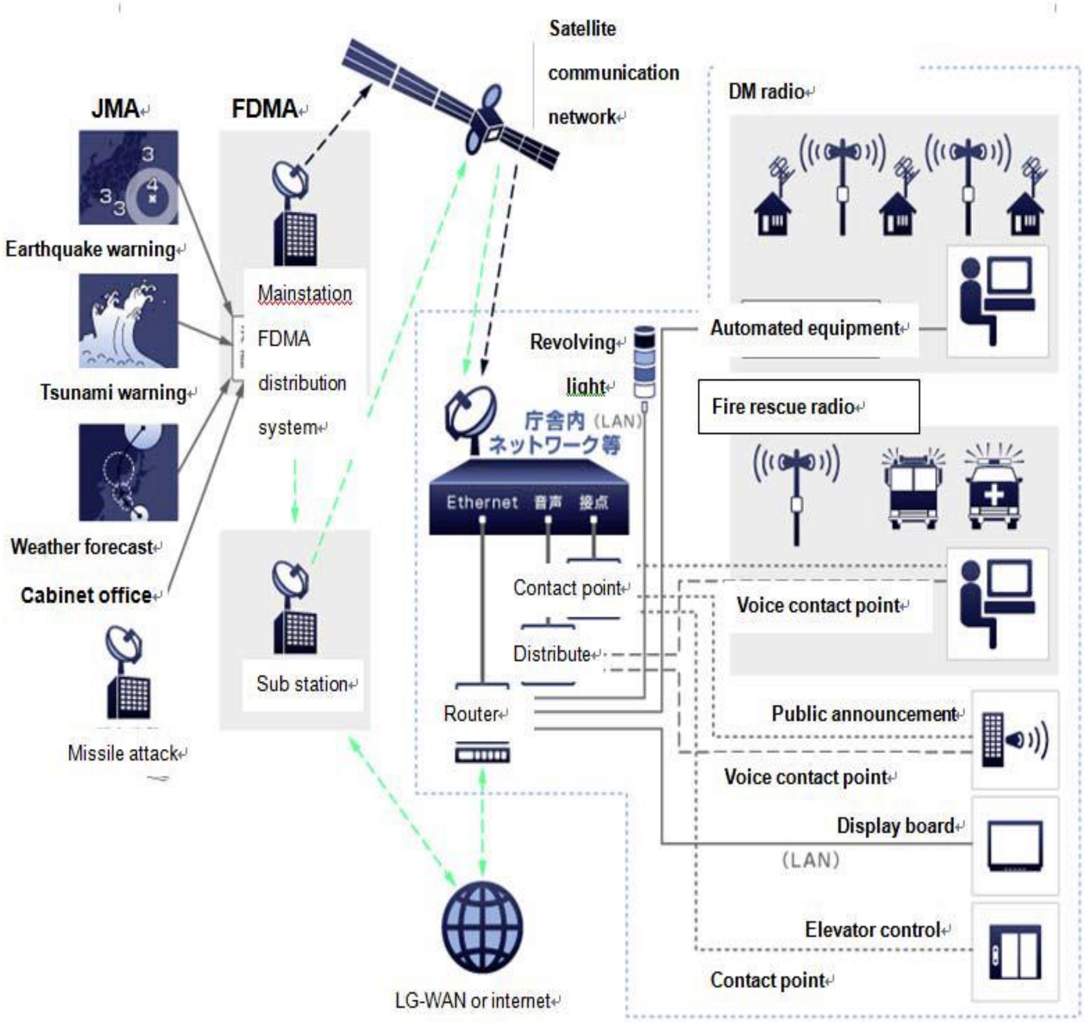


Figure 31: J-Alert Automatic communication system

c. Observation System for Earthquakes -

In order to constantly monitor seismic activity, the JMA and other relevant organizations install and maintain seismometers that are used for estimating the location of the epicenter and magnitude of an earthquake as well as for tsunami forecasts, and seismic intensity meters that measure the intensity of ground motion, in numerous places nationwide. As soon as an earthquake occurs in or around Japan, the JMA analyzes the data from various seismometers and seismic intensity meters. Within about two minutes, it issues a seismic intensity information report for earthquakes of intensity 3 or greater, and within about five minutes issues an earthquake information report indicating the epicenter and magnitude of the earthquake and the seismic intensity in the municipalities where strong shaking was observed.

d. Distant Earthquake Information and International Tsunami Advisories

JMA monitors seismic activity not only around Japan but also worldwide. If a tsunami generated by a distant earthquake is expected to hit the Japanese coast and possibly cause disastrous conditions, JMA issues Tsunami Warnings/Advisories in the same way as for local tsunamis. When a major earthquake occurs somewhere far from Japan, the Agency issues Distant Earthquake Information to the public.

Tsunamis spread ocean-wide regardless of the borders of countries, and can cause serious damage in multiple coastal areas. In order to protect human life and property against tsunami hazards, we must work together with overseas related organizations. Within a worldwide framework for a tsunami warning system, countries exchange observational data and information to enable earthquake/tsunami detection and measures against expected tsunamis as early as possible. Japan has a wealth of experience and knowledge on tsunamis, and JMA, in such an international partnership role, plays a major part in contributing to tsunami disaster management measures in other countries. When a large earthquake occurs in the Sea of Japan, the northwestern Pacific region or the Indian Ocean, the Agency analyzes the related observation data and quickly provides International Tsunami Advisories to the countries in each region. These advisories contain information on the earthquake and the possibility of tsunamis, and are used in the recipient countries for the implementation of emergency action such as nationwide tsunami warnings and official evacuation.

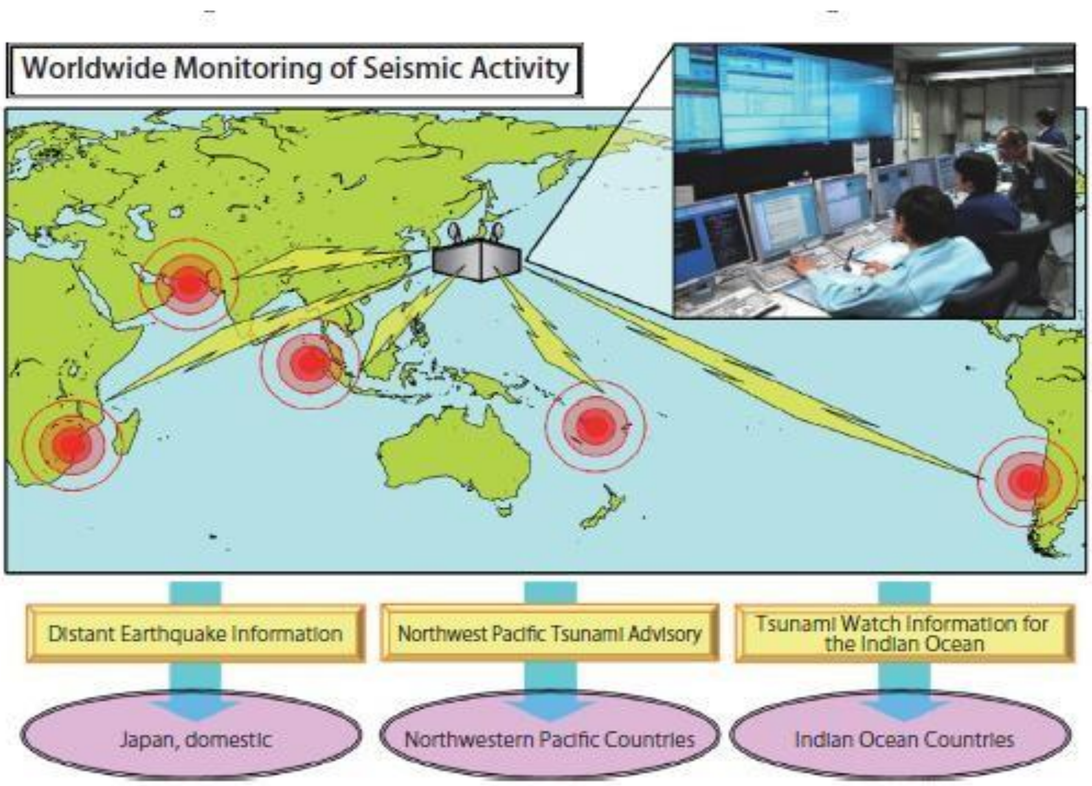


Figure 32: Worldwide Monitoring of Seismic Activities by JMA

2.3 Tsunami Disaster

Tsunami is a Japanese word with the English translation: "harbor wave". In the past, tsunamis have been referred to as "tidal waves" or "seismic sea waves". The term "tidal wave" is misleading; even though a tsunami's impact upon a coastline is dependent upon the tidal level at the time a tsunami strikes, tsunamis are unrelated to the tides. (Tides result from the gravitational influences of the moon, sun, and planets.) The term "seismic sea wave" is also misleading. "Seismic" implies an earthquake-related generation mechanism, but a tsunami can also be caused by a non-seismic event, such as a landslide or meteorite impact.

Tsunamis are also often confused with storm surges, even though they are quite different phenomena. A storm surge is a rapid rise in coastal sea-level caused by a significant meteorological event - these are often associated with tropical cyclones.

A tsunami is a series of very long waves generated by rapid, large-scale disturbances of the sea—the sudden displacement of a large volume of water, generally from the raising or lowering of the seafloor caused by:

- earthquakes
- landslide
- volcanic eruptions
- explosions
- meteorites

Once a tsunami has been generated, its energy is distributed throughout the water column, regardless of the water depth, and the waves travel outward on the surface of the ocean in all directions away from the source, much like ripples caused by throwing a rock into a pond. The wavelength of the tsunami waves and their period depend on the generating mechanism and the dimensions of the source event.

In the deep ocean, the height of a tsunami from trough to crest can range from a few centimeters to a meter or more depending on the generating source. Tsunami waves in the deep ocean can travel at high speeds for long periods of time over distances of thousands of kilometers and lose very little **Tsunami** energy in the process. The deeper the water, the greater the speed of tsunami waves is. A tsunami wave can travel more than 800 kilometers per hour (km/h) in the deep ocean, but slows to 30 to 60 km/h in shallow water near land. But, amazingly, pass under a ship in the ocean with those aboard the vessel hardly noticing.

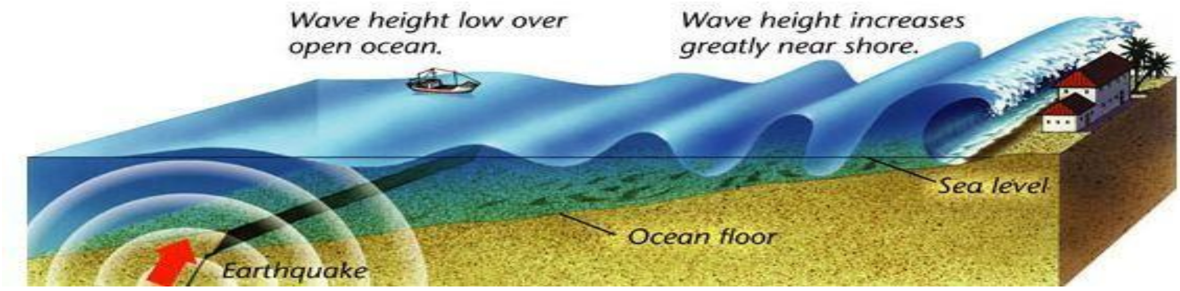


Figure 33: Tsunami wave travels

Tsunamis arrive at a coastline as a series of successive crests (high water levels) and troughs (low water levels) usually 10 to 45 minutes apart. As the tsunami waves become compressed near the coast, their wavelengths are shortened, and the wave energy is directed upward—thus considerably increasing the height and force of the waves.

Tsunami waves may smash into the shore like a wall of water or move ashore as a fast moving flood or tide—carrying along everything in their path. The historic record shows that many tsunamis have struck with devastating force, sometimes reaching heights of 30 to 50 meters. It should be remembered that a tsunami run-up of more than 1 meter is dangerous due to the strong force it has. Flooding by individual waves typically lasts from 10 to 30 minutes, but the danger can last for hours. Greater tsunamis tend to move inland with the derbies and sometimes with massive fire.

Generally, coasts and islands with steep fringes or surrounded by barrier reefs are safer than those with gradually rising fringes or those that are exposed to open ocean. This is because reefs can absorb much of the oncoming waves' impact and deep coastlines do not allow tsunamis to slow down and grow into deadly towers of water.

a. The physics of a tsunami

Tsunamis can have wavelengths ranging from 10 to 500 km and wave periods of up to an hour. As a result of their long wavelengths, tsunamis act as shallow-water waves. A wave becomes a shallow water wave when the wavelength is very large compared to the water depth. Shallow-water waves move at a speed, *c*, that is dependent upon the water depth and is given by the formula:

$$c = \sqrt{gH}$$

Where *g* is the acceleration due to gravity (= 9.8 m/s^2) and *H* is the depth of water.

In the deep ocean, the typical water depth is around 4000 m, so a tsunami will therefore travel at around 200 m/s, or more than 700 km/h.

For tsunamis that are generated by underwater earthquakes, the amplitude of the tsunami is determined by the amount by which the sea-floor is displaced. Similarly, the wavelength and period of the tsunami are determined by the size and shape of the underwater disturbance.

As the tsunami propagates across the ocean, the wave crests can undergo refraction (bending), which is caused by segments of the wave moving at different speeds as the water depth along the wave crest varies.

b. Tsunami as it approaches land

As a tsunami leaves the deep water of the open-ocean and travels into the shallower water near the coast, it transforms, as the water depth decreases, the tsunami slows. The tsunami's energy flux, which is dependent on both its wave speed and wave height, remains nearly constant. Consequently, as the tsunami's speed diminishes, its height grows. This is called shoaling. Because of this shoaling effect, a tsunami that is unnoticeable at sea, may grow to be several meters or more in height near the coast.

The increase of the tsunami's wave height as it enters shallow water is given by:

$$\frac{h_s}{h_d} = \left(\frac{H_d}{H_s}\right)^{\frac{1}{4}}$$

where h_s and h_d are wave heights in shallow and deep water and H_s and H_d are the depths of the shallow and deep water. So a tsunami with a height of 1 m in the open ocean where the water depth is 4000m would have a wave height of 4 to 5 m in water of depth 10 m.

Just like other water waves, tsunamis begin to lose energy as they rush onshore - part of the wave energy is reflected offshore, while the shoreward-propagating wave energy is dissipated through bottom friction and turbulence. Despite these losses, tsunamis still reach the coast with tremendous amounts of energy. Depending on whether the first part of the tsunami to reach the shore is a crest or a trough, it may appear as a rapidly rising or falling tide. Tsunamis may reach a maximum vertical height onshore above sea level, often called a run-up height, of tens of meters.

c. Measuring or observing a tsunami

In the deep ocean, a tsunami has small amplitude (less than 1 meter) but very long wavelength (hundreds of kilometers). This means that the slope, or steepness of the wave is very small, so it is practically undetectable to the human eye. However, there are ocean observing instruments that are able to detect tsunamis.

d. Tide Gauges

Tide gauges measure the height of the sea-surface and are primarily used for measuring tide levels. These consist of an acoustic sensor connected to a vertical tube open at the lower end which is in the water. The acoustic sensor emits a sound pulse which travels from the top of the tube down to the water surface, and is then reflected back up the tube. The distance to the water level can then be calculated using the travel time of the pulse. This system filters out small-scale effects like wind waves and has the capacity to measure sea-level changes within 1mm accuracy.

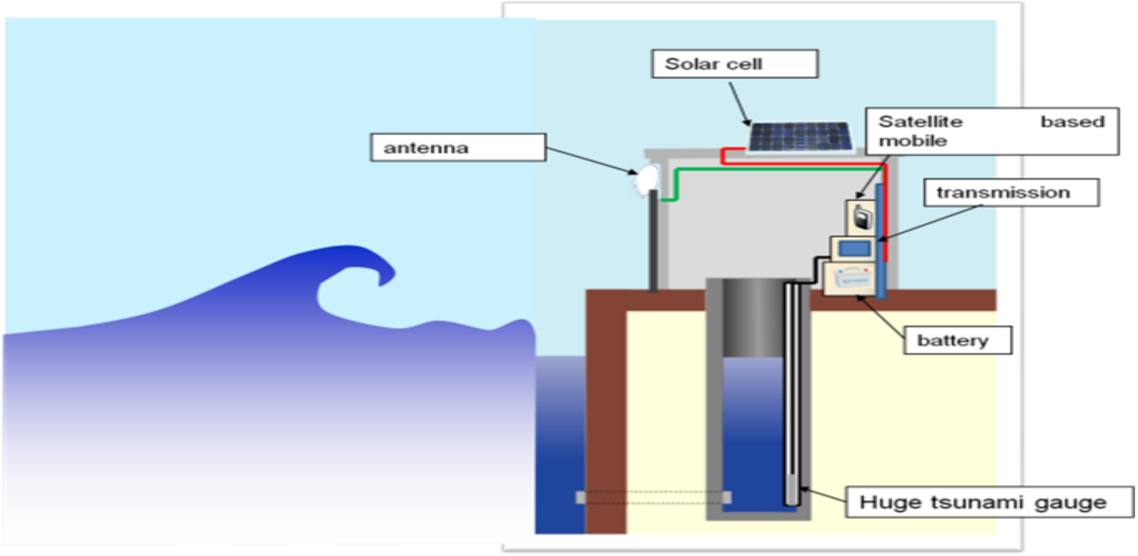


Figure 34: Tsunami Identification through tide gauge.

The tide gauge at Cocos Island observed the tsunami on December 26th 2004 as it passed by the island, as shown in these observations made during December.

e. Tsunami Monitoring by Satellites

Satellite altimeters measure the height of the ocean surface directly by the use of electro-magnetic pulses. These are sent down to the ocean surface from the satellite and the height of the ocean surface can be determined by knowing the speed of the pulse, the location of the satellite and measuring the time that the pulse takes to return to the satellite. One problem with this kind of satellite data is that it can be very sparse - some satellites only pass over a particular location about once a month, so you would be lucky to spot a tsunami since they travel so quickly. However, during the Indian Ocean tsunami of December 26th 2004, the Jason satellite altimeter happened to be in the right place at the right time.

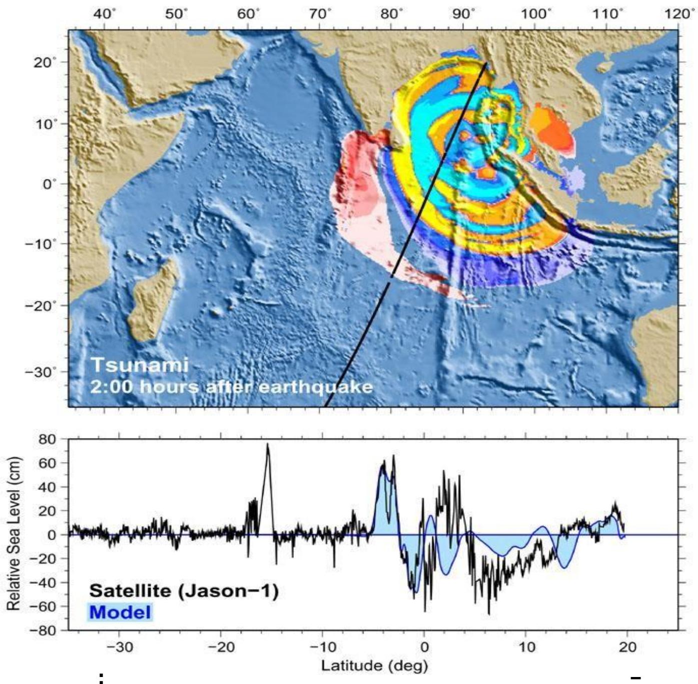


Figure 35: J-Alert Automatic communication system

The picture shows the height of the sea surface (in blue) measured by the Jason satellite two hours after the initial earthquake hit the region southeast of Sumatra (shown in red) on December 26, 2004. The data were taken by a radar altimeter on board the satellite along a track traversing the Indian Ocean when the tsunami waves had just filled the entire Bay of Bengal. The data shown are the differences in sea surface height from previous observations made along the same track 20-30 days before the earthquake, showing the signals of the tsunami.

2.4 Tsunami Early Warning System in Sri Lanka

Tsunami was affected in 14 coastal districts in Sri Lanaka. These are namely, Jaffna, Mullaitivu, Tricomalee, Baticaloa, Ampara, Hambantota, Matara, Galle, Kalutara, Colombo, Gampaha, Puttalam, Mannar and Kilinochchi Districts. There are two subduction zones which are having a risk of Tsunami to Sri Lanka such as Sumatra and Macaron. The National Early Warning Centre will generate the messages to disseminate timely advisories to the vulnerable communities.
The Meteorological Department of Sri Lanka which is the focal point for issuing tsunami alert and warning messages. Once the Technical Agencies issues an alert or warning message, the DMC is responsible for dissemination of these messages to the vulnerable communities in the vulnerable areas. The dissemination from national level to district/division/Grama Niladari level is done by using telephones, radio communications, tsunami warning towers, SMS, cell broadcast etc. The most important part is the dissemination among the community. The community based trainings on disaster management had been provided by the DMC for strengthening community level message dissemination and the precautions.

Sri Lanka is being using the End to End Multi- Hazard system for tsunami disaster early warning in a different angle. One of the uniqueness of the warning system could be utilized to any disasters for any time in the day. However, the efficiency and the effectiveness will be depending on the time, culture, community, demography and sometime weather condition etc.

2.5 Tsunami Early Warning System in Japan

a. Earthquake and Tsunami Monitoring

Located in one of the most active seismic and volcanic zones in the world, Japan is frequently affected by earthquakes and volcanic disasters. JMA operationally monitors seismic and volcanic activity throughout the country and issues relevant warnings and information to mitigate damage caused by disasters related to earthquakes, tsunamis and volcanic eruptions.

To monitor earthquakes, JMA operates an earthquake observation network comprised of about 200 seismographs and 600 seismic intensity meters. It also collects data from over 3,600 seismic intensity meters managed by local governments and the National Research Institute for Earth Science and Disaster Prevention (NIED). The data collected are input to the Earthquake Phenomena Observation System (EPOS) at the headquarters in Tokyo and the Osaka District Meteorological Observatory on a real-time basis.

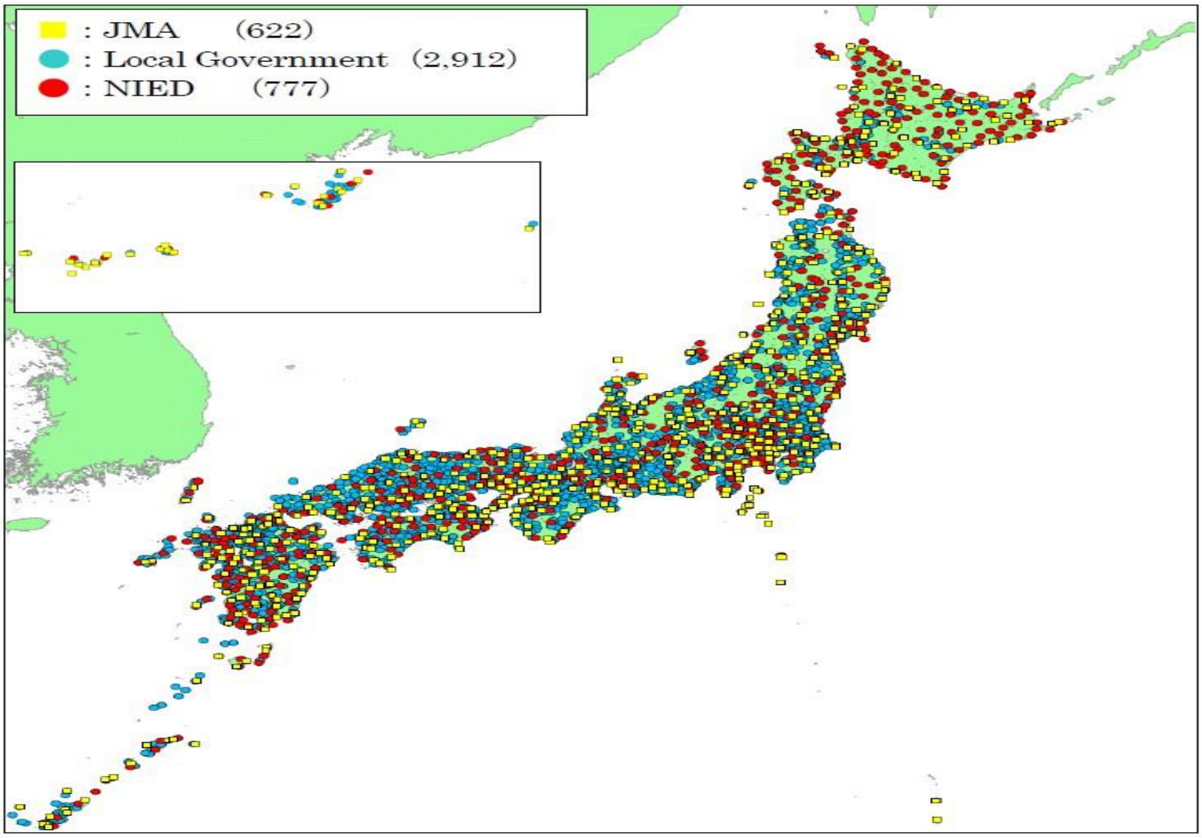


Figure 36: Seismic intensity network monitoring by JMA

Figure 37: JMA Seismic station

b. Earthquake Information issued by Japan Meteorological Agency

Earthquake Early Warnings (EEWs) are issued slightly after an earthquake occurs. There are no earthquake predictions which tell us occurrence of earthquake in advance.

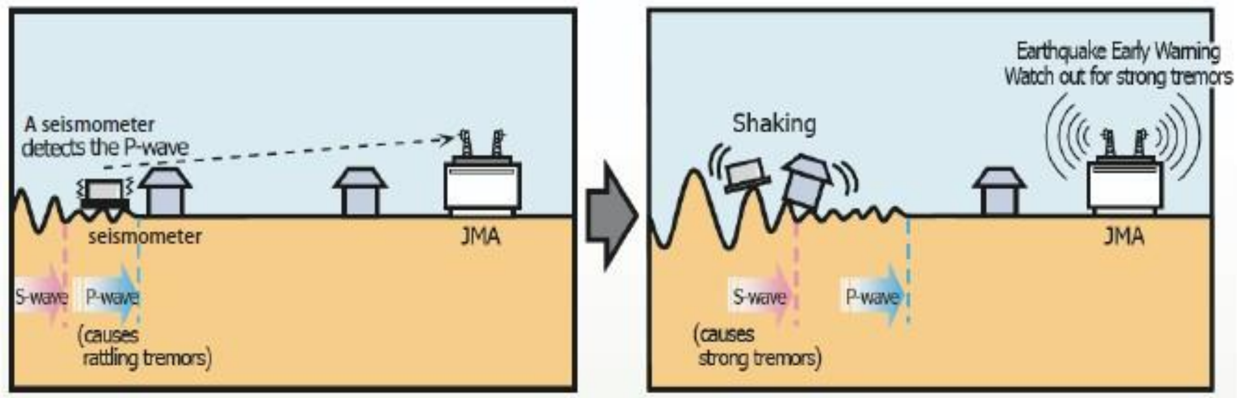


Figure 38: Earthquake Early Warning

As soon as an earthquake occurs, the EEW system uses seismometers located near the epicenter to calculate the hypocenter, magnitude and P-wave data detected by the area that will be subjected to strong shaking, and provides a first announcement. EEWs are transmitted promptly. A sophisticated observation system to detect seismic waves quickly, technology that enables forecasting from very weak shaking and communication technology for prompt dissemination are the elements that enable JMA to issue EEWs.

The Earthquake Early Warning is aimed at mitigating earthquake-related damage by allowing countermeasures such as promptly slowing down trains, controlling elevators to avoid danger and enabling people to quickly protect themselves in various environments such as factories, offices, and houses and near cliffs.

Title	Content and Timing to be issued
Seismic Intensity Information	This information is issued within about two minutes from an earthquake to provide information on the regions where seismic intensity of 3 or more was observed. Each prefecture is divided into 2 or more regions.
Earthquake Information	The location and magnitude of an earthquake is determined within about three minutes. In case of no tsunamigenic earthquake, the message of "Tsunami is not expected" is added.
Earthquake and Seismic Intensity Information	This information indicates the location of the hypocenter, magnitude, and name of regions, cities, towns and villages in which intensity of 3 or more was observed.
Information on seismic intensity at each site	All stations which observed intensity of 1 or more, hypocenter location and magnitude of the earthquake are provided.
Shake Map	Just after an earthquake, the shaking-intensity map is prepared. This map is produced taking into account local geological conditions and observed seismic intensity
Information on the number of earthquakes	When earthquakes occur frequently in a same place called earthquake swarm, hourly/daily number of earthquakes is provided.

Table 2: Earthquake Early Warning Content

c. Response to an Earthquake Early Warning System

The period between the Earthquake Early Warning and the arrival of strong tremors is very short, i.e. a matter of seconds (or between several seconds and a few tens of seconds). As a result, areas that are close to the focus of the earthquake may not receive the Earthquake Early Warning transmission before strong tremors hit.

And there are limits to the accuracy of the Earthquake Early Warning, such as the estimated seismic intensity. This is because the system is necessarily dependent on very short-term data. It is important to be aware of these features and limitations when responding to Earthquake Early Warnings.

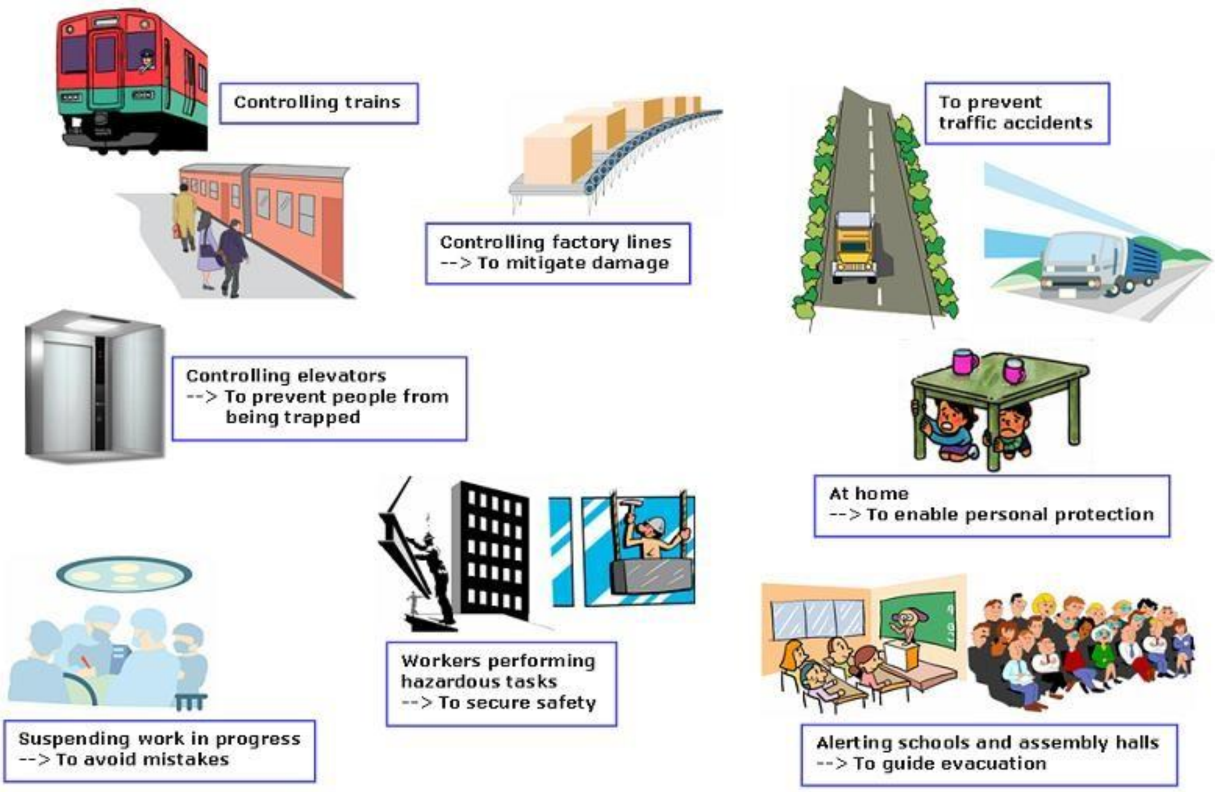


Figure 39: Response to an Earthquake Early Warning

d. Tsunami Monitoring Network

When tsunamis are observed, JMA issues tsunami observation information including observation points, tsunami heights and expected times of arrival. The Agency operates about 70 tidal gauge stations and also collects real-time sea-level data from stations operated by the Ports and Harbors Bureau (Ministry of Land, Infrastructure, Transport and Tourism), the Geographical Survey Institute and the Japan Coast Guard. Currently, JMA issues tsunami information using data from about 170 stations.

Figure 40: Response to an earthquake early warning

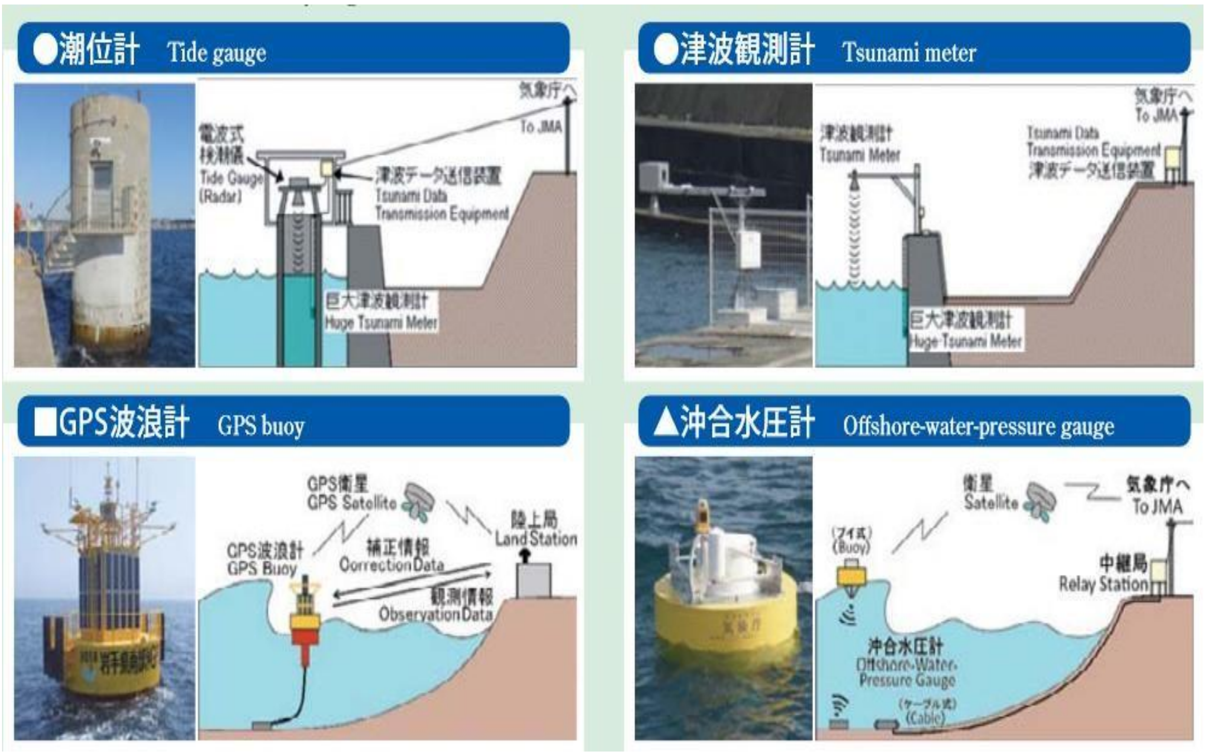


Figure 41: Tsunami Observation Mechanism

e. Open-ocean buoys

An array of stations is deployed in the Ocean. These stations give detailed information about tsunamis while they are still far off shore. Each station consists of a sea-bed bottom pressure recorder which detects the passage of a tsunami. (The pressure of the water column is related to the height of the sea-surface). The data is then transmitted to a surface buoy via sonar. The surface buoy then radios the information to the Tsunami Warning Center via satellite. The system has considerably improved the forecasting and warning of tsunamis.

Figure 42: Open ocean buoy by JMA

f. Costal Tsunami Observation system

This system can operate a wireless network with a solar panel (potovoltatic) system and a storage battery system even in the event of a disaster, when commercial power and wired information networks are inaccessible. With the coastal tsunami monitoring system, network cameras were installed at different places to monitor the coasts. The plan is to transmit real time video data to the City Hall Disaster Prevention Headquarters via a wireless system, along with data from the wave height gauge set up on the Coast. At the heart of this wireless system is a multi-service access concentrator capable of handling data transfer over three wireless networks—a 5G wireless link capable of transmitting videos, a 920MHz band specified low-power wireless system suitable for transmitting wave height data, and WiFi. The system is also powered by a self-sustaining power supply system consisting of PV panels and a lithium ion storage battery unit.

Figure 43: Ccoastal Tsunami Observation System

g. Tsunami Information issued by JMA

When a large earthquake occurs in a sea area, the Japan Meteorological Agency (JMA) estimates the possibility of tsunami generation from seismic observation data. If disastrous waves are expected in coastal regions, JMA issues a Tsunami Warning/Advisory. A numerical simulation technique is used to estimate tsunami potential and propagation. After an earthquake occurs, Tsunami Warnings /Advisories must be issued immediately to enable evacuation before the wave strikes coastal areas. To enable immediate issuance of Tsunami Warnings / Advisories, JMA has conducted computer simulation of tsunamis with earthquake scenarios involving various locations and magnitudes, and the resulting information on tsunami arrival times and heights is stored on a database. If a large earthquake occurs, the operation system quickly calculates its hypocenter and magnitude, searches the tsunami database referring to these calculations, and selects the closest-matching results from the database. Using the estimated height of the tsunami for each coastal region, JMA issues a Tsunami Warning/Advisory.

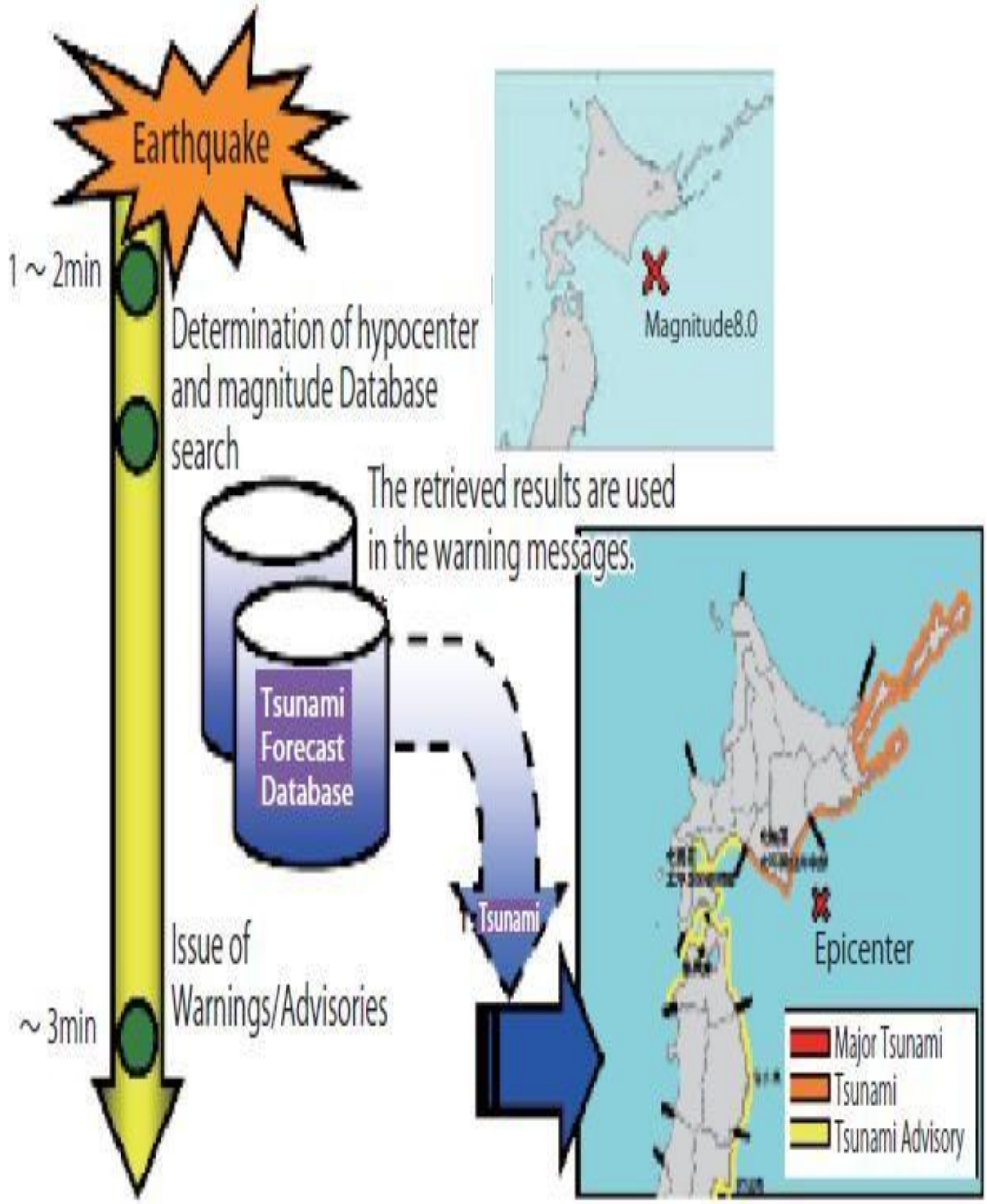


Figure 44: Issuing of Tsunami warning advisories source JMA

Flow of information about Earthquake and Tsunami

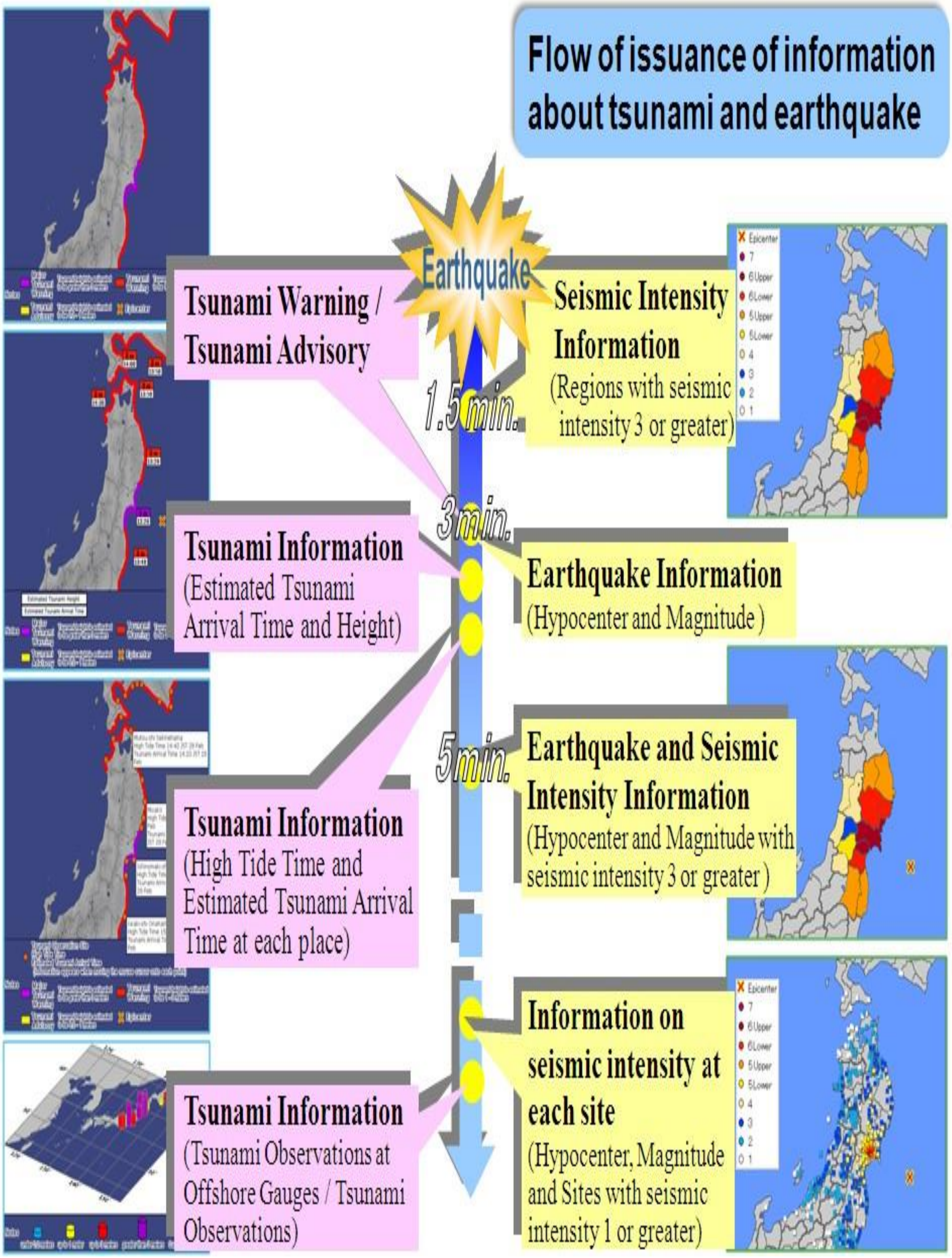


Figure 45: Flow of information, earthquake and tsunami Source JMA

h. Tsunami Warning/Advisory

When an earthquake occurs that could generate a disastrous tsunami in coastal regions of Japan, JMA issues Major Tsunami Warnings, Tsunami Warnings and/or Tsunami Advisories for individual regions based on estimated tsunami heights around three minutes after the quake (or as early as two minutes in some cases).

Immediately after an earthquake occurs, JMA promptly establishes its location, magnitude and the related tsunami risk. However, it takes time to determine the exact scale of earthquakes with a magnitude of 8 or more. In such cases, JMA issues an initial warning based on the predefined maximum magnitude to avoid underestimation.

When such values are used, estimated maximum tsunami heights are expressed in qualitative terms such as "Huge" and "High" in initial warnings rather than as quantitative expressions. Once the exact magnitude is determined, JMA updates the warning with estimated maximum tsunami heights expressed in quantitative terms.

Tsunami Warning/Advisory categories and action to be taken

	Estimated maximum tsunami height: Quantitative expression	Estimated maximum tsunami height: For huge earthquakes	Action to be taken	Expected damage
Major Tsunami Warning	over 10 m (10m < height)	Huge	Evacuate from coastal or river areas immediately to safer places such as high ground or a tsunami evacuation building. Tsunami waves are expected to hit repeatedly. Do not leave the evacuation location until Tsunami Warnings are cleared.	Wooden structures are expected to be completely destroyed and/or washed away; anybody exposed will be caught in tsunami currents.  (Most wooden structures washed away due to the tsunami in 2011)
	10m (5m < height ≤ 10m)			
	5m (3m < height ≤ 5m)		Keep evacuating to higher and higher ground wherever possible!  Educational video "Escape the Tsunami" (JMA)	
Tsunami Warning	3m (1m < height ≤ 3m)	High		Tsunami waves will hit, causing damage to low-lying areas. Buildings will be flooded and anybody exposed will be caught in tsunami currents. Toyokoro-cho (2003) 
Tsunami Advisory	1m (20cm ≤ height ≤ 1m)	(N/A)	Get out of the water and leave coastal areas immediately. Do not engage in fishing or swimming activities until Advisories are cleared. 	Anybody exposed will be caught in a strong tsunami currents in the sea. Fish farming facilities will be washed away and small vessels may capsize. 

Figure 46: Tsunami warning / Advisory categories and action to be taken Source JMA

i. Tsunami Information

When Tsunami Warnings and/or Advisories are issued, Tsunami Information bulletins on matters such as estimated tsunami heights and arrival times are subsequently issued.

Messages about tsunami	Indication
Tsunami Information (Estimated Tsunami Arrival Time and Height)	Estimated arrival times and heights of the tsunami for relevant tsunami forecast regions. * The estimated tsunami arrival time for each tsunami forecast region is the time at which it is expected to hit first in any part of that area. Hence, in some coastal regions, tsunamis may hit after the estimated time.
Tsunami Information (High Tide Time and Estimated Tsunami Arrival Time at each place)	The high tide times and estimated arrival times of the tsunami at selected points.
Tsunami Information (*1) (Tsunami Observations)	Arrival times and heights of the tsunami observed at tide gauges or tsunami meters.
Tsunami Information (*2) (Tsunami Observations at Offshore Gauges)	Tsunami arrival times and heights observed at offshore gauges, and related tsunami heights along the coast in the corresponding forecast region estimated from offshore observations.

Table 3: Tsunami Information Table

(*1) Issuance of Tsunami Information based on Tsunami Observations

JMA announces the arrival times and initial movement of the first observed waves in coastal areas, and also provides information on the arrival times and scale of the highest waves observed as of the time of issuance.

As tsunami waves can hit repeatedly and those arriving later may be higher, it is inadvisable to abandon evacuation if the initially observed waves are small. Accordingly, when a Major Tsunami Warning and/or a Tsunami Warning is in effect and observed tsunamis appear much smaller than estimated, JMA uses the phrase "Currently Observing" rather than actual values to keep people aware that higher waves may still approach.

Expressions used for observed maximum heights in coastal areas

Warnings/advisories in effect	Observed heights	Information bulletin expressions
Major Tsunami Warning	Height ＞ 1 m	Actual values
	Height ≦ 1 m	"Currently Observing" announcements
Tsunami Warning	Height ≧ 0.2 m	Actual values
	Height ＜ 0.2 m	"Currently Observing" announcements
Tsunami Advisory	(all cases)	Actual values ("Slight" for very small waves)

Table 4: Tsunami Information base on Tsunami Observation

(*2) Issuance of Tsunami Information based on Tsunami Observations at Offshore Gauges

JMA announces the arrival times and initial movements of the first observed waves offshore, and also provides information on the arrival times and scale of the highest waves observed as of the time of issuance. JMA also announces estimated data for tsunami waves in coastal areas (arrival times of initial waves and arrival times/heights of maximum waves) for each tsunami forecast region expected to be affected.
JMA does not provide actual values for observed tsunami heights offshore or estimated maximum tsunami heights for coastal areas until the thresholds for issuance are reached (in the same way as those for coastal areas) in consideration of the related influence on people's evacuation. When a Major Tsunami Warning and/or a Tsunami Warning is in effect and estimated tsunami heights for coastal areas are small, JMA uses the phrase "Currently Observing" for observed heights offshore and "Currently Investigating" for estimated heights in coastal areas to keep people aware that higher waves may still approach.

Expressions used for observed maximum heights at offshore gauges and estimated maximum heights in coastal areas.

Warnings/advisories in effect	Estimated tsunami heights for coastal areas	Information bulletin expressions
Major Tsunami Warning	Height ＞ 3 m	Actual values for observed heights at offshore gauges and estimated heights in coastal areas
	Height ≦ 3 m	"Currently Observing" for offshore observations and "Currently Investigating" for estimated heights in coastal areas
Tsunami Warning	Height ＞ 1 m	Actual values for observed heights at offshore gauges and estimated heights in coastal areas
	Height ≦ 1 m	"Currently Observing" for offshore observations and "Currently Investigating" for estimated heights in coastal areas
Tsunami Advisory	(all cases)	Actual values for observed heights at offshore gauges and estimated heights in coastal areas

Table 5: Estimated Tsunami height

For gauges more than 100 km offshore, JMA does not announce the relevant estimated tsunami heights for coastal areas due to the difficulty of determining which tsunami forecast regions waves will reach from offshore gauges. Announcement of tsunami heights observed at such gauges is begun when JMA issues an information bulletin detailing actual values for observed and estimated heights from other offshore gauges closer to the coast. Until this time, the phrase "Currently Observing" is used.

j. Tsunami Forecast

After an earthquake occurs, if no damage is expected, JMA issues Tsunami Forecasts.

Forecasted sea level changes	Message
No tsunami is expected	"No tsunami is expected." (To be included in Earthquake Information.)
Tsunami height less than 0.2 meters is expected	No damage is expected because sea level changes will be less than 0.2 m, and no special action is needed.
Slight sea level changes are expected to continue after Tsunami Warnings/advisories are cleared	Particular attention is needed when fishing, swimming or engaging in other marine activities because tsunami-related sea level changes have been observed and may continue for a while.

Table 6: Tsunami Forecasting

k. Observation, Forecasting and Warning of Disaster Risks

Observation systems that can accurately detect disaster risks in real-time have been progressively improved for establishing early warning systems, supporting early evacuation and response activities, and thereby reducing disaster damage. Organizations involved in disaster reduction, especially the JMA, use 24-hour systems to carefully monitor various natural phenomena and weather conditions. In addition to observed information the JMA issues a wide range of forecasts, warnings and advisories.

l. Information and communication system for Issuing Evacuation Advisory and Order

When a disaster occurs or is imminent, residents may start evacuating on their own volition, and the mayor of the municipality may also issue an evacuation advisory or order. It is effective for municipalities to prepare a manual explaining the criteria regarding disaster situations that require the issuance of evacuation advisories or orders, including under what situation and to what area, thereby helping the mayor’s quick decision.

The Cabinet Office, with new disaster management information being released and lessons from past disasters, has revised the “Guidelines for Producing a Decision and Dissemination Manual for Evacuation Advisories and Orders” entirely in April 2013, and has requested that each local government review and revise its criteria for issuing advisories or orders for evacuation.
Also, it has requested relevant prefectural and national entities to proactively give advice in the efforts of municipalities making such revision.
The new guidelines place an emphasis on making it easy to understand the criteria for issuing advisories or orders for evacuation, and urges municipalities to issue them early enough without fear of resulting in unnecessary action.

Efforts will be to support, in full cooperation with relevant entities, the municipalities to understand and recognize the purpose of this guideline and make progress in amending the criteria for issuing evacuation advisories or orders.

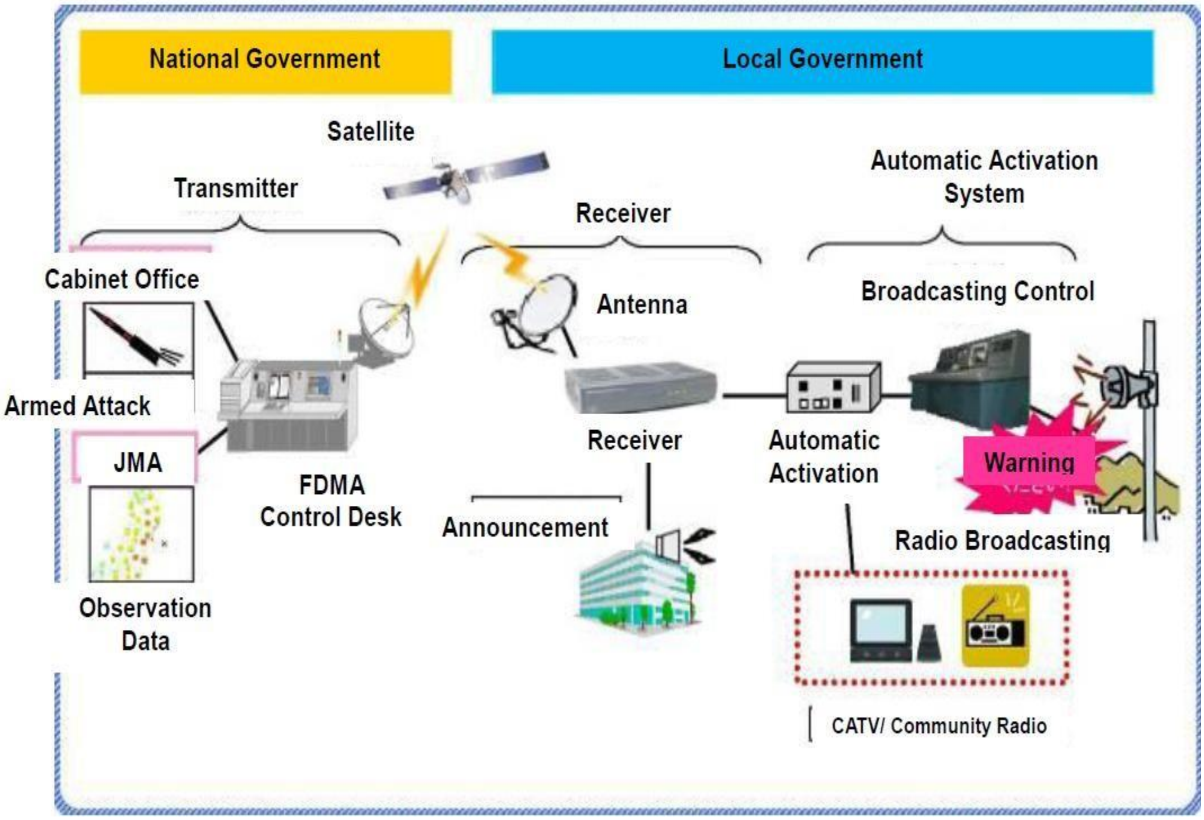


Figure 47: Early Warning Communication System

m. Central Disaster Prevention Radio Network

The development of a quick and accurate communications system is essential for the effective use of disaster early warning information. For this purpose, an online system has been built, linking the JMA with disaster management organizations of the national and local governments and media organizations.

Disaster management organizations have also been developing radio communications networks exclusively for disasters: the CAO's Disaster Prevention Radio Communication System, which connects national organizations; the Fire Disaster Management Radio Communication System, which connects firefighting organizations across the country; and prefectural and municipal disaster management radio communications systems, which connect local disaster management organizations and residents.

The Cabinet Office has established the CAO's Disaster Prevention Radio Communication System to link with designated government organizations, designated public corporations and prefectural governments, providing communications by telephone, fax, data transmission, video conferencing and video transmission of disaster situations from helicopters and other sources.

Simultaneous wireless communications systems using outdoor loudspeakers and indoor radio receivers are used to disseminate disaster information to residents. Tsunami and severe weather warnings are widely provided to citizens via TV and radio broadcasts.

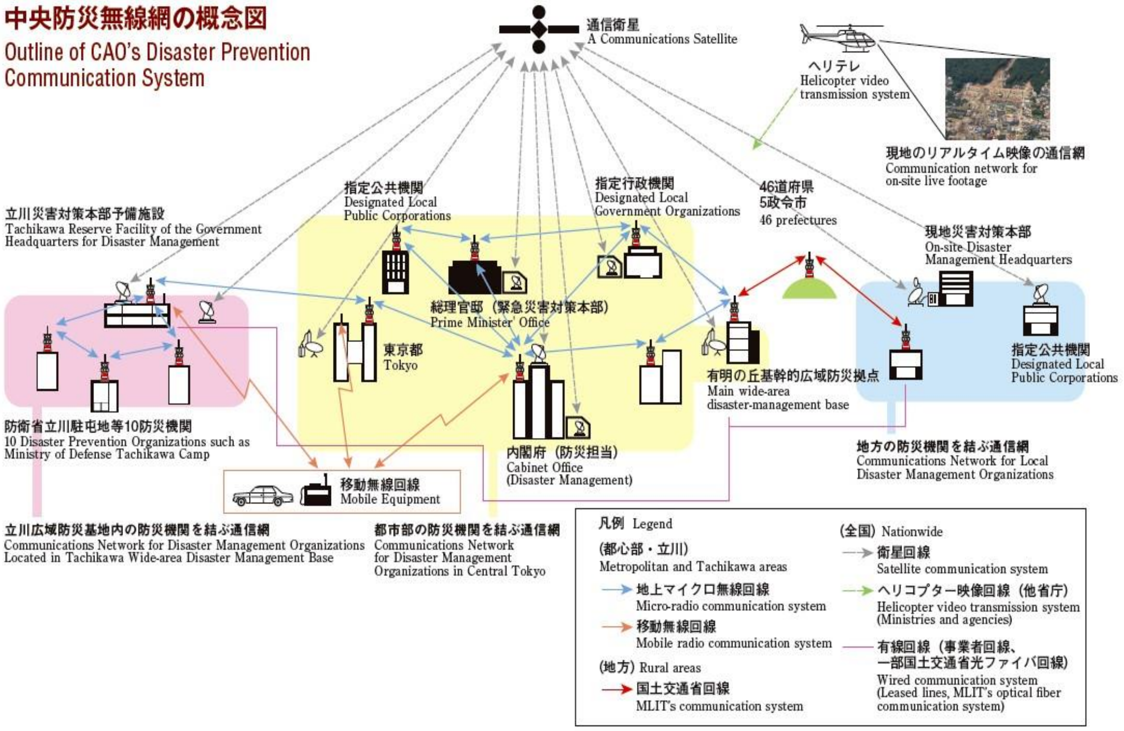


Figure 48: Disaster Pretension communication system source – Cabinet office, Government of Japan

Chapter III – Research Design

a. Specific Aims

- To identify current issues in the early warning system in Sri Lanka
- To analyze the effectiveness of the established early warning system to face future Tsunamis in the in Sri Lanka, in comparison with Japanese early warning system

b. Expected Results

- Validation of the effectiveness of the Tsunami early warning system in Sri Lanka
- Comparison of the EW systems in Sri Lanka and Japan
- Identification gaps in the current Early Warning System and remedial measures for further improvements.

3.1 Methodology

Data and information collected from the both countries. A survey data was gathered by using a questionnaire method that is utilized to correct, analyze and interpret the views of a group of people. All the information transfer in to the data which can be used. Data are analyzed by ranking method. Primary data were converted to the secondary data. Data collection method and category of data represent in the 3.2 and 3.3 in this report.
Finally, the conclusion and recommendation could be forwarded through SWOT analysis techniques.

3.2 Data Collection

- Information and data of the current Tsunami early warning system in Sri Lanka.
- Collect the information and data of the Tsunami early warning system in Japan.
- Shearing of Practical experience.
- Presentations and discussions in the ADRC VR 2016B in Japan.
- Review of Literatures delivered by Universities in japan with lesson learn.
- Site visit in tsunami and earthquake areas in the Japan.
- Hyogo prefecture Disaster Management Centre and Hyogo police
- Exhibitions / Museums and other relevant sources.
- Web sites.
- Japan Meteorological Agency (National Government)
- Tsunami Storm Surge Prevention Station, Osaka (Local Government)
- Disaster Science and Education Research Center, Wakayama University (Academia)
- Tsunami Education Centers
- DRI museum and other observation
- Meeting with relevant stakeholders and communities.
- 2011 Tsunami Site visit and ccurrent preparedness and mitigation activities in Japan
- ADRC VR program field visits.
- Questioner survey

3.2.1 Category of Data collected for evaluation, both Japan and Sri Lanka

I. General Information
- Land size
- Population density
- Gini co- efficient
- Human development index. (HID)
- Political intervention
- Cultural
- Language
- Type of messages

II. New Technologies for Early Warning (satellite etc.)
- Availability of very high sophisticated (Satellite etc) early warning methods
- Public response for new technological early warning
- Operational arrangement of new early warning system
- Reliability of new early warning systems
- Maintenance and upgrades

III. Conventional Methods for Early Warning (Drum, bells, flags, etc.)
- Available conventional communication methods
- Public response for conventional early warning
- Operational arrangement of conventional early warning system
- Reliability of conventional warning systems
- Maintenance and upgrades

IV. Social media and electronic media (blog, bulletin board, Facebook, twitter, etc.) for Early warning
- Contribution of electronic media for early warning
- Contribution of social media for early warning

V. Other Network for Early Warning (Self-defense, Military & police etc.)
- Contribution of other network for early warning

VI. Rehearsals, Testing of Early Warning Equipment
- Voice testing (Live testing)
- Communication testing

VII. Different Administrative levels of Warning Dissemination
- National level
- Subnational level
- Community level

VIII. Timing for Tsunami Early Warning (Alert, Warning, Evacuation, Stand down)
- Satisfaction of delivery and reception of EW messages

IX. Awareness of tsunami early warning system

Public awareness on warning mechanism

X. Effectiveness of Early Warning

Effectiveness of having early warning system and early warning

XI. Cost and Benefit investment for EW systems

Investment of early warning system

3.3 Data Evaluation Method

Data were analyzed by ranking analyzing method. Rank were arrayed from Zero to ten (0 – 10). Zero (0) = Dissatisfied, 10 (ten) = 100% Satisfied, 5 (five) = Average of Satisfaction. Bellow five (5) = Bellow average (need to be improved). Above five (5) = More than average but there are gaps to be fulfilled. In the other hand, it does imply the value from Zero (0) to ten (10) is equal to the 0% to 100%.

Data will be analyzed by the descriptive statistics method such as Mean, Median, Mode, Range, Standard deviation etc.

All relevant data will be compared by qualitatively and quantitatively.

Percentage is used to describe the data proposition of the sample.

In order to present the data, Pie charts, bar charts tables will be used.

Analyzed the Gaps and consequences through SWOT.

3.4 Limitation of the Research

1. Time: Three months' period is not enough to gather the data with other works.
2. Field observation: Inadequate discussions has had with affected communities and relevant officers.
3. Literature review: Lack of available research on the early warning system.
4. Analysis: Simple analysis method has been used to discuss the result.
5. Inadequate questioner survey in the Japan in each prefecture.

Chapter IV – Result and Discussion

Data were evaluated under the main section of Early Warning and Dissemination in the disaster management field. Result and discussion would be based on the questioner survey. Early Warning and Dissemination has further categorized into 11 sub field and it is indicated in the questioner thus giving more elaboration of the Early Warning field. In order to analyzed the relevant data, it has to be divided to many sub areas. All the collected data were summarized and averaged. Averaged data were representing as percentage except the general information such as land size, population density and HDI. Both Japan and Sri Lankan data were displayed in the following tables with the detail discussion.

4.1 Evaluation of General Information to Early Warning

No	Activity	Japan	Sri Lanka	Description
1	Land size	378	65	(000) Japan is 06 time bigger than Sri Lanka. Cost line length of Japan 29751 Km and SL is 1340
2	Population density	336	325	(Sq km) Density is almost same. But Japan has high Population distribution in coastal area due to 70% land belong to mountainous and forest while SL is 30%
3	Gini co- efficient	25-30	40-45	Inequality of income or wealth is higher in the SL.
4	Human development index. (HID)	20 (0.89)	73 (0.75)	Life expectancy, Education and per capita income are high in japan it is rank no. 20.
5	Political intervention on EW	10 %	30 %	Sri Lanka has a more political intervention than japan.
6	Cultural impact on EW	05 %	40 %	Sri Lanaka has multi-culture
7	Language barrier for EW	10 %	60 %	SL is multinational country. Many language have been using in Sri Lanaka specially Sinhala ,Tamil and English.
8	Number of EW messages issue for an incident.	90 %	70 %	SL issue only four numbers of EW message for one incident but japan issue more number of different EW messages to the community for tsunami.

Table 7: Evaluation of General Information to Early Warning

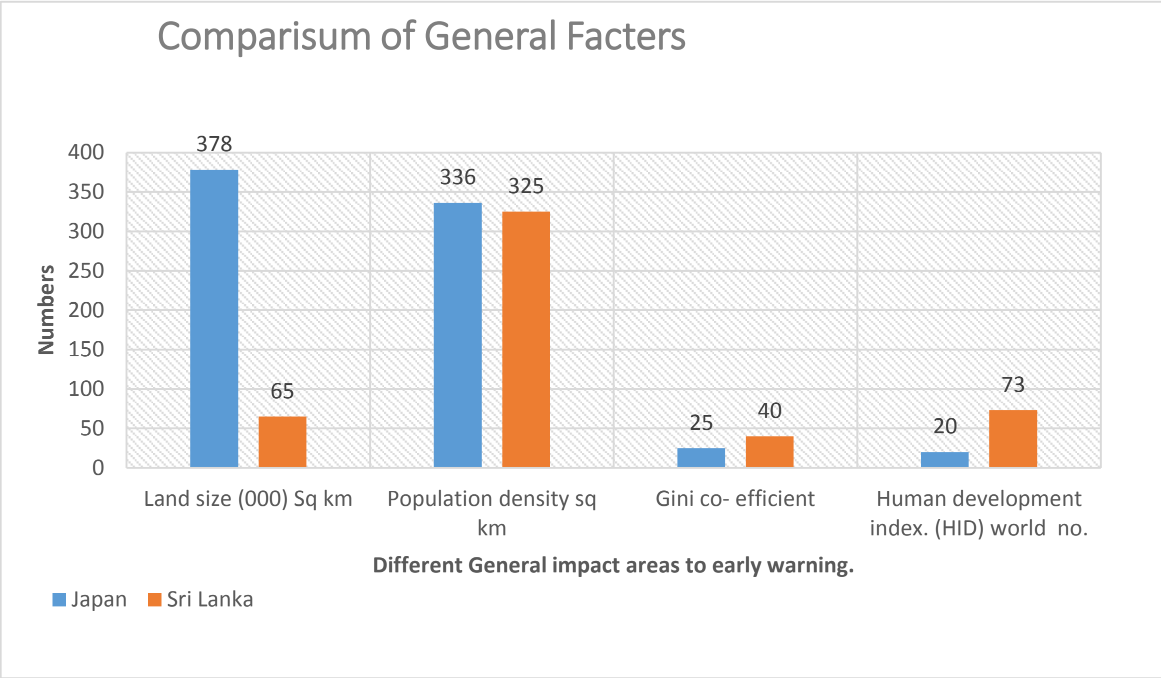


Figure 49: Comparison chart of General factors

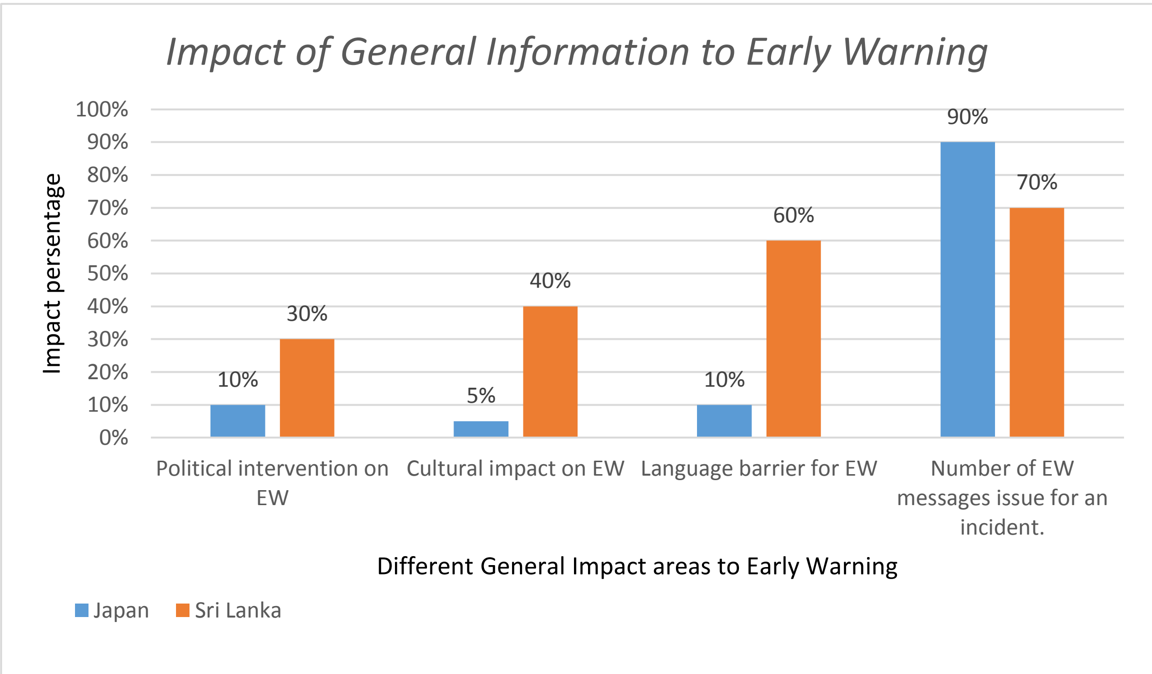
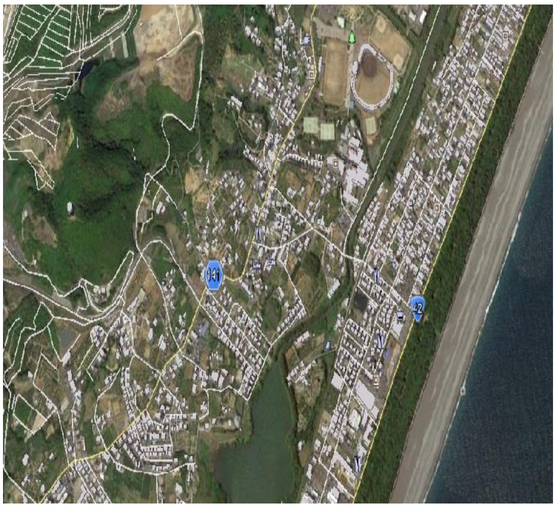


Figure 50: Comparison of impact - chart

Japan is 06 time bigger than Sri Lanka. Cost line length of the Japan is 29751 Km while Sri Lanka cost line is 1340 km. It is 22 times bigger than the Sri Lankan coast line. Density of the both countries are almost same. But Japan has high Population distribution in coastal area due to 70% land belong to mountainous and forest while Sri Lanka has 30% mountains and forest. The factors which are high coast line population and long length of the coast line of the

Japan would created the disadvantage for tsunami early warning. There is a high potential of chance to missing the early warning of entire vulnerable costal belt by tower failure. That will be affect more peoples in the vulnerable area due to high density of population in the costal belt. However, these facts can be ignoring with the available warning systems. Inequality of income is high in Sri Lanka. Life expectancy, Education and per capita income are high in japan it is rank no.20. The low wealth also effects to the receive the warning due to unavailability of radios, television, mobile phones and internet facilities to some vulnerable communities in Sri Lanka. Political intervention to the early warning dissemination in Sri Lanka is bit higher than the japan. It is also effect to consume the timing and delay the warning dissemination. Sri Lanka is multinational country therefore it has multi-culture. Many languages have been using in Sri Lanka specially Sinhala, Tamil and English. Sri Lanka has to pass the messages based on the culture and language in order to control the panic situation. For instance, east and the north of the country are majority of Tamils and the moor. Because of that disseminate the messages by Tamil languages is more effective. Also Sri Lanka is tourist country. All the costal belt is enriched with foreigners. Therefore, it is very important to pass the messages by English language too.



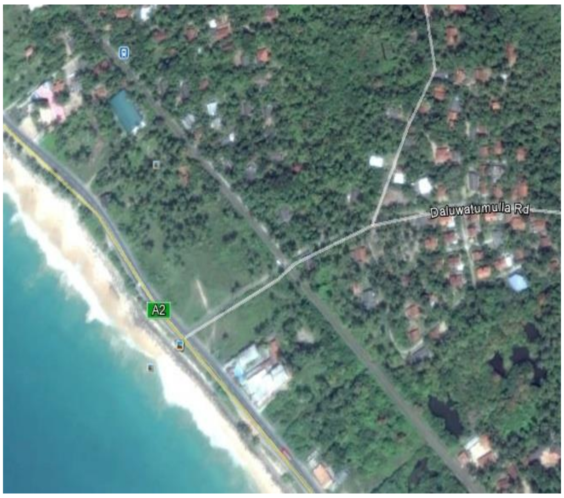


Figure 51: Japan and Sri Lankan costal belts.

4.2 Use of New Technologies for Early Warning

No	Activity	Japan %	Sri Lanka %	Description
I.	Available new technological early warning methods	90	60	Japan has more systems with satellite. But SL has only few system early warning towers, no satellite.
II.	Public response for new technological early warning	90	80	Japan is highly depending on this new system thus available in everywhere. SL also highly depend but systems are not common.
III.	Operational arrangement of new early warning system	95	70	Japan has fully automatically warning system. But SL depend initial data and information getting from regional countries.
IV.	Reliability of new early warning systems	80	60	Though it is reliable in both countries, SL don't have system. Tsunami rare in SL than Japan.
V.	Maintenance and upgrades	90	80	Japan has technology, skill and, knowledge. SL has to hire the all. Big issue to SL.

Table 8: Use of New Technologies for Early Warning

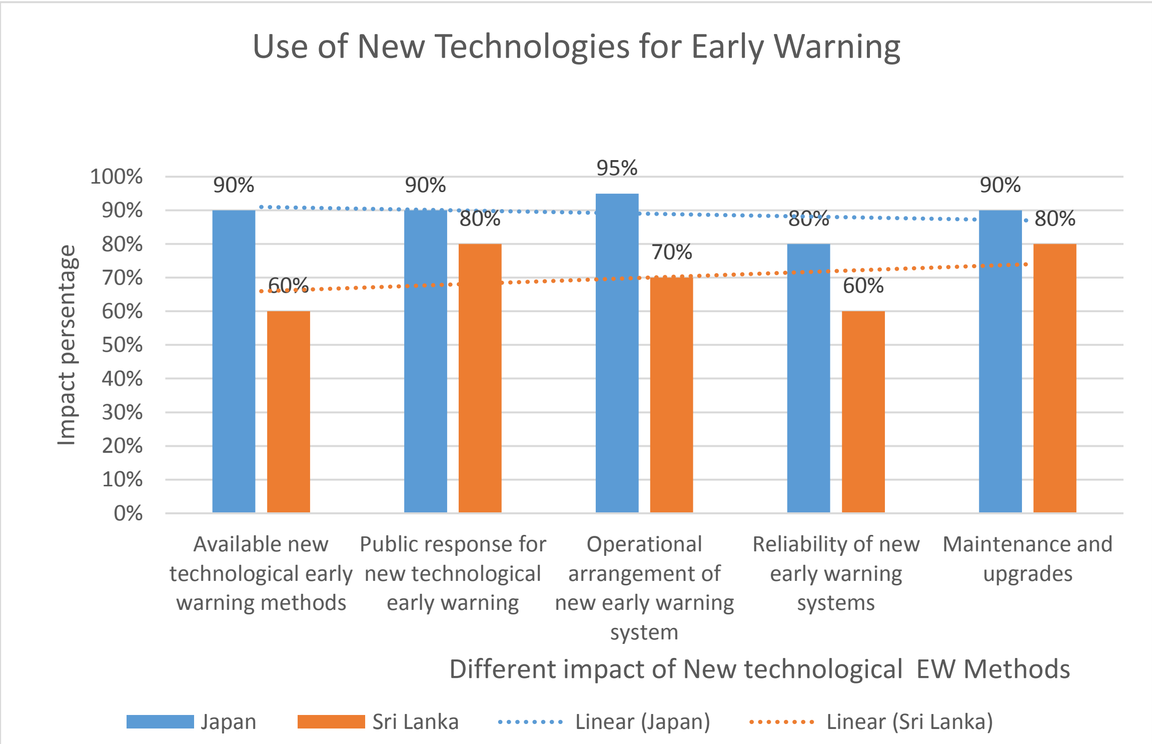


Figure 52: Comparison chart of use new technology for EW

Japan has early warning systems based on the satellite operation. They have own satellite which is J-Alert. But Sri Lanka does not have any satellite. A few systems have operated by satellite technology which are early warning towers and Thuraya satellite communication. Japan is highly depending on these new technological early warning systems. Those systems are allocated to where it is vulnerable locations in the country. Japan has fully automatic warning system. Peoples in the Japan are highly response to the new technological warning systems like early warning towers. Sri Lanka also highly depend on the new technological early warning system but systems are not commonly available in the country. Only 77 early warning towers are available in costal belt in the country. Also Sri Lanka is being depending on the initial data and information which are forwarding by regional countries specially India, Indonesia and Australia. Though these new technological systems are reliable in both countries, Sri Lanka don't have proper maintenance mechanism due to unavailability of such technological expertise in the country. This is big issue of Sri Lanka. Japan has their own technology, skill and, knowledge. However, the Tsunami is very rare in Si Lanka than Japan. In the past decade the only one tsunami has recorded in Sri Lanka while having more tsunami in Japan.

4.3 Use of Conventional Communication Methods for Early Warning (CCM)

No	Activity	Japan %	Sri Lanka %	Description
I.	Available conventional communication methods	05	40	SL has mostly depend on CCM due to lack of new systems while japan has very few.
II.	Public response for conventional early warning	10	40	SL has high respond but it is depending on person to person and other factors also. eg. environment and location etc.
III.	Public responsibility for conventional early warning	05	60	This system has depend on the national system and information receiving system.
IV.	Reliability of conventional warning systems	10	30	Most popular in rural area in SL. But very low reliability in both countries.
V.	Maintenance and upgrades	80	60	Japan has proper maintenance mechanism if the systems are exist.

Table 9: Use of Conventional Communication Methods for Early Warning (CCM)

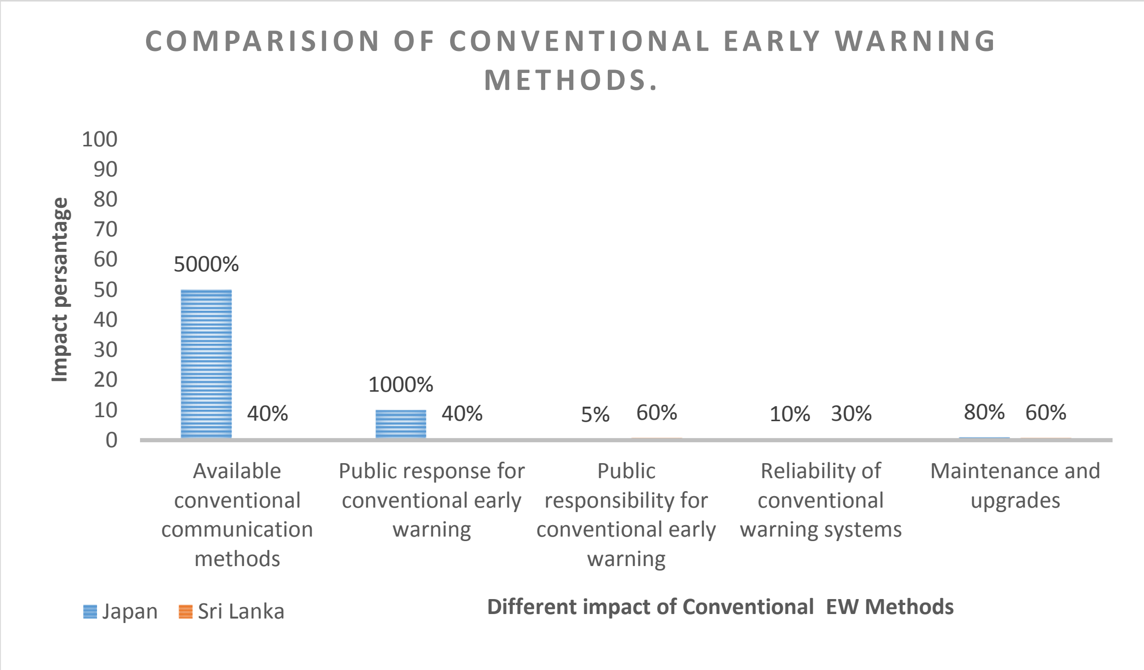


Figure 53: Comparison chart of Conventional EW

Sri Lanka has mostly depended on Conventional Communication Methods due to lack of new technological systems. Sri Lanka has been highly responded to these conventional communication systems but it is depending on person to person and also the other factors which are environment, location, number of system available, kind and type of the communication system etc. This system also has depended on the national system because they cannot predict the tsunami. Therefore, they have to be alert on the national warning and information receiving system. If there is a gaps or failure in national system, entire conventional communicational system has failed. Due to low cost of operation and maintenance this CCM is very much popular in rural area in Sri Lanka. Japan has a very few systems are operations such as megaphone and public address systems. Japan has proper maintenance mechanism if the systems are existing. But it is very low reliability in both countries.

4.4 Utilization of social media and electronic media for Early warning

No	Activity	Japan %	Sri Lanka %	Description
I.	Contribution of electronic media for early warning	50	30	Japan has separate media channel for EW. SL has depend on Pvt and Govt channels.
II.	Contribution of social media for early warning	30	20	Both countries predominantly using but SL has not proper mechanism to use for EW.

Table 10: Utilization of social media and electronic media for Early warning

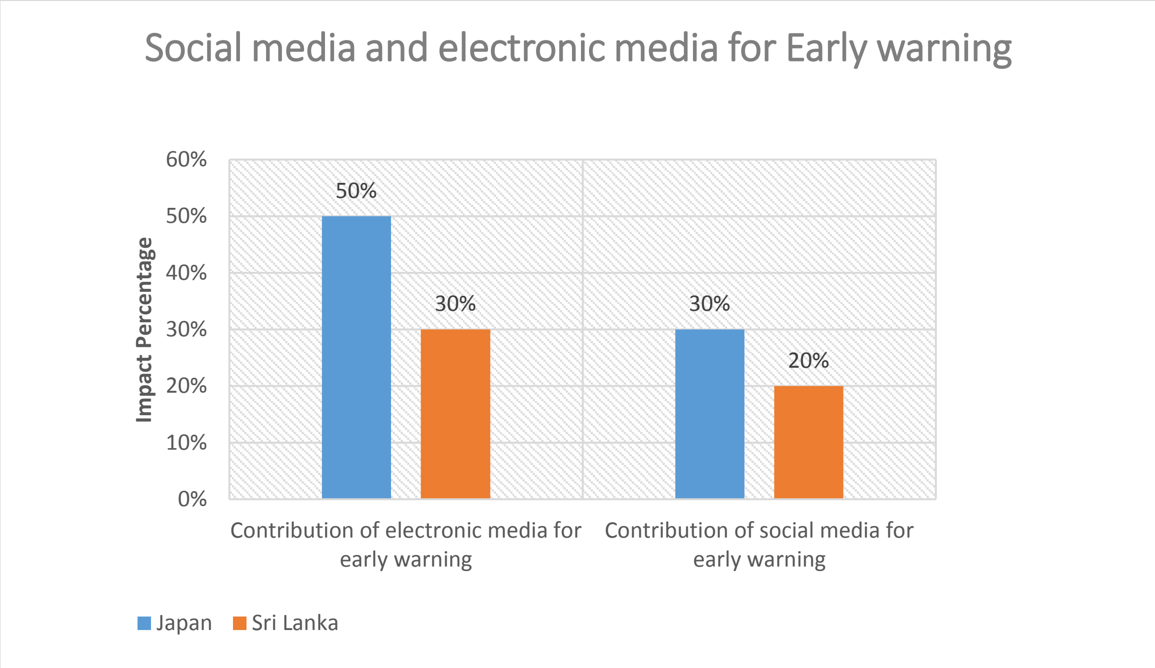


Figure 54: Comparison chart of social and electronic media for EW

Japan has separate media channel for early warning and they can operate independently. Sri Lanka has depended on privet and government broadcasting and telecasting channels and those are not working at 24 hours' basis. Both countries predominantly using but Sri Lanka has not proper mechanism to use this media during night time. Face book, twitter, WhatsApp, Skype, messenger, viber and other social media are being used by the both countries. But in the night no one has responded to getting warning from social media.

4.5 Use of Other Network for Early Warning (Military & police etc.)

No	Activity	Japan %	Sri Lanka %	Description
I.	Contribution of other network for early warning	10	40	Japan use own system while SL more utilized other com systems such as Military, Police etc.

Table 11: Use of Other Network for Early Warning (Military & police etc.)

Japan use their own communication system while Sri Lanka has been more utilized the other communication systems such as Military, Police, fire brigade, coast guard, railway etc. This is very reliable when the main system has fail the other alternative system has existed. Also peoples more confidence when it is coming more communication channels.

4.6 Rehearsals, Testing of Early Warning Equipment

No	Activity	Japan %	Sri Lanka %	Description
I.	Voice testing (Live testing)	80	50	Japan frequently testing. SL has not satisfactory level.
II.	Communication testing	80	70	Both countries are above average level.
III.	Public awareness on rehearsals.	90	60	SL peoples are always panic.

Table 12: Rehearsals, Testing of Early Warning Equipment

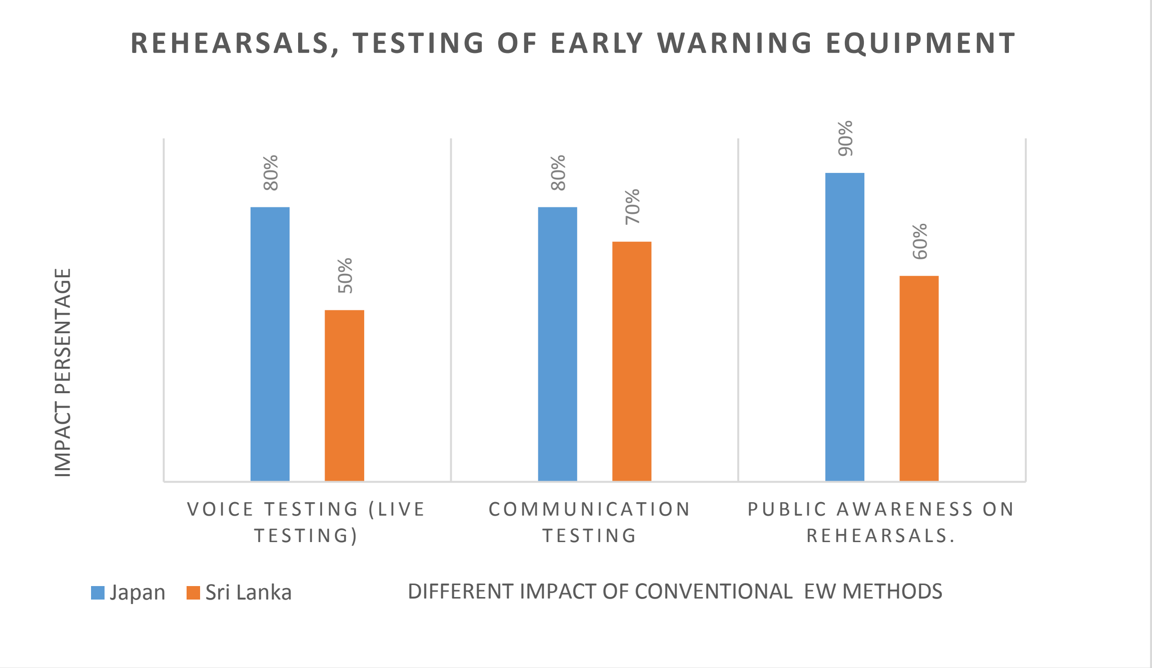


Figure 55: Comparison chart of Rehearsals, testing of EW equipment

Japan has frequently testing of their communication systems by full strength. But Sri Lanka has not operated the system frequently in the full strength. Sri Lanka is being used poll testing method to test the early warning towers in order to prevent the panic. But it does not imply the workability of the voice dissemination of the warning towers. Both countries are being displayed the above average level in the testing of communication systems.

4.7 Responsibility of Different Administrative levels for Warning Dissemination

No	Activity	Japan %	Sri Lanka %	Description
I.	National level	10	80	SL has higher responsibility to EW at any time.
II.	Subnational level	95	82	Prefecture level has very high responsibility while districts of

				SL also has almost same responsibility.
III.	Community level	05	30	SL communities have high responsibility due to inadequate EW equipment. But japan has national EW system to cater all the vulnerable areas.

Table 13: Responsibility of Different Administrative levels for Warning Dissemination

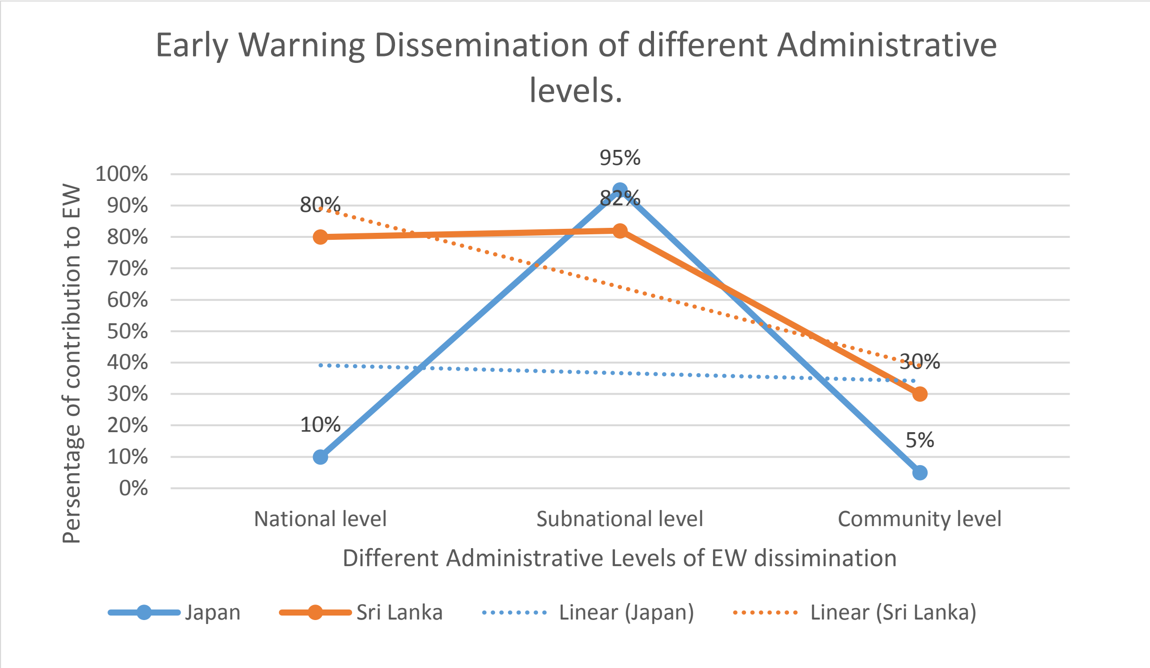


Figure 56: Comparison chart of different administrative levels of EW

Sri Lanka national government has higher responsibility to early warning dissemination at any time. Districts of Sri Lanka also has same responsibility to pass the message to the district level and community level. Sri Lankan village level communities have high responsibility to disseminate the early warning among their communities due to inadequate technological early warning equipment. Japan has each prefectures level early warning system to cater all the vulnerable areas in the country. But japan don't have any responsibilities to warn the people nationally. If Prefecture could not able to disseminate the national government pass the messages immediately through the broadcasting, telecasting and by using other communication techniques.

4.8 Evaluation of communication in the Tsunami Early Warning

No	Activity	Japan %	Sri Lanka %	Description
I.	Satisfaction of EW messages delivery	95	80	SL also satisfied if the messages received on time.

II	Satisfaction of reception of EW messages	90	70	Japan direct delivery and received. But SL has different integrated system.
III.	Identification of tsunami disasters.	95	50	Japan has technical body. SL has mostly depend on International body. Japan Peoples can feel the earthquake. But SL isn't it.

Table 14: Evaluation of communication in the Tsunami Early Warning

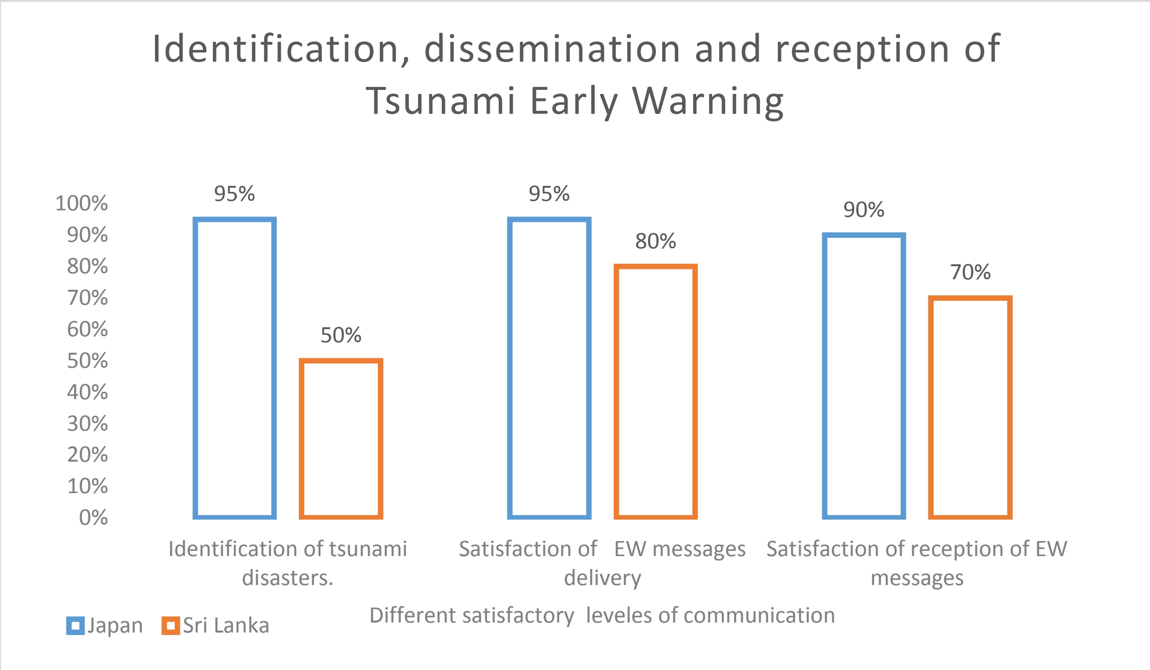


Figure 57: Comparison chart of Identification, dissemination and reception of EW

Most of the time Japan Peoples can feel the earthquake. They have their own sign for tsunami disaster, the people can take the decision to move to safe location. Japan has direct delivery and receiving early warning mechanism without depend other nation. Japan has high technical body to analyze the situation. Sri Lanka also satisfied if the messages received on time but Sri Lanka has to be depend on the International body to get the tsunami warning. However, Sri Lanka has integrated early warning system pass the message as soon as possible to the vulnerable communities.

4.9 Awareness of tsunami early warning system

No	Activity	Japan %	Sri Lanka %	Description
I.	Public awareness on warning mechanism	90	50	Japan has good awareness among the public. Awareness has to be improved in SL.

Table 15: Awareness of tsunami early warning system

Japan has an excellent awareness system among the public sector. Japan had several tsunamis in the past decade. This experiences also convenience to peoples in alert to the tsunami awareness. Therefore, most of the peoples know the tsunami. However, if the peoples know tsunami, they could not have about where to go, what time to go, what to bring etc. Especially they don't know about transportation arrangement. Therefore, all the peoples are come with their vehicles. That would be major issue in the japan. The japan warning system has not yet concern about this issues. Sri Lanka has to improve the public awareness on early warning mechanism with the all the communities. Only the coastal communities know the tsunami warning system. But the other communities should have also known the warning system in order to prevent the impact from tsunami disasters.

4.10 Effectiveness of Early Warning System

No	Activity	Japan %	Sri Lanka %	Description
I.	Effectiveness of having early warning system.	96	95	Both countries high priorities.
II	Effectiveness of early warning	95	87	Effectiveness of the EW depend on the Quality of messages and the warning received by public.

Table 16: Effectiveness of Early Warning System

Both countries have given higher priorities on early warning systems to save the lives and properties. Effectiveness of the early warning system depend on the Quality of messages and the warning received by public. More tsunamis have to be happened in order to analyze the effectiveness of the warning system. If there is no tsunami effectiveness also zero. Therefore, Japan has high effectiveness why it is operated in 2011 tsunami successfully. But in Sri Lanka do not have any tsunami after the establishment of tsunami towers simply after 2004.

4.11 Analysis of Cost and Benefit investment for EW Systems

No	Activity	Japan %	Sri Lanka %	Description
I	Investment of early warning system	98	70	Comparatively SL also spend more money on EW.
II	Satisfaction of investment to the early warning system	95	74	Japan has high vulnerability to tsunami. But SL has only one experience. Based on the frequency of tsunami occurrence, Investment should be focused on Multi hazards warning system.

Table 17: Analysis of Cost and Benefit investment for EW Systems

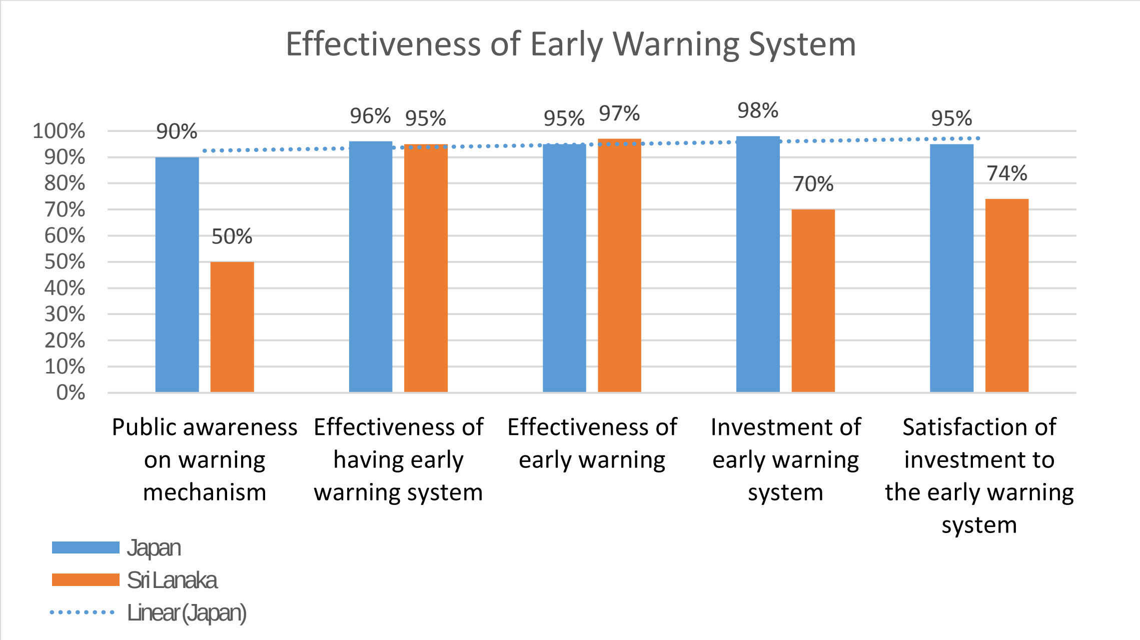


Figure 58: Comparison chart of effectiveness of EW

Comparatively Sri Lanka also invested more than the return of investment to the tsunami early warning system. But Sri Lanka has only one experience in 2004 tsunami. Bu Japan has high vulnerability to tsunami. Based on the frequency of tsunami occurrence, Investment has focused on Multi hazards angle. Therefore, it can be used to any impending disasters.

a. Available and usability of the Early Warning Methods

The following table has described the technological and conventional early warning systems that are used in the world and also it is display the magnitude of use in Japan and Sri Lanka.

No	Communication System	Japan	Sri Lanka
	Land line telephones / CDMA	Common use	Common use
	Early Warning Towers	Commonly using for every disasters	77 towers only. Use for tsunami and cyclone.
	Satellites	Common use	Tower operation and very rare use for communication.
	SMS	Always using for public at any network.	Use for selected costumes. Cannot operate all the networks.
	Cell Broadcast	No in use	Fairly use but do not have confidence.
	VHF/HF Radio	Common use	Moderate use.

	Mobile Network	Common use	Common use. But in the disaster, network system jammed.
	Television channels	24 hours channels	No 24 hours channel. During night time have to inform to start the telecast.
	Radio channels	24 hours channels and separate channels are available.	No 24 hours' channel. During night time have to inform to start the telecast
	Press media	Not enough time	Not enough time
	Fax	Ordinary use	Only 15 minutes can use after that system jammed.
	Email	Always using.	Selected personal only
	Internet	Common use	Messages Upload but not common use.
	By Vehicles – Announcements	Fire brigade, police vehicles and helicopters are used.	No helicopters used, police, military vehicles.
	NGOs and CBOs	Not much involved	High involved.
	PA Systems	Commonly fixed systems are being used.	Always used. Mobile Pa systems also use.
	Mega phones.	Very common	Very common.
	Hand Sirens	Not use	Ordinary use.
	Electric Sirens	Common use	A very few use.
	Temple and church bells	Not use	Common use.
	Mosque PA system	Not use.	Common use
	Riders/ Push Bicycle & Motor	Not use	Ordinary use.
	Early Warning Committees (Door to Door)	Not prominent. No mechanism.	Committees are available. In the disasters cannot find the committee.
	Flags and different colour cords.	Rare use	Ordinary use
	Other institutional communication systems	Japan has dedicated line to communication. Therefore, not depend on other communication.	SL always depend on other communication system such as military, police, fire brigade etc.
	Mouth to mouth.	Very rare	Higher relationship among the communities. Most common practices.

Table 18: Available and usability of the Early Warning Methods

b. SWOT analysis

SWOT technique uses for analyze the strengths, weakness, opportunities and threats of the early warning mechanism in the japan and Sri Lanka.

Strengths	Weakness,
Opportunities	Threats

Figure 59: SWOT windows

The following table has displayed the comparison and different values of early warning perspective of view such as information dissemination, reception, operation, other indirect impact of warning etc. between two countries and within the country. This table results also link with the

No	Information effect to EW	Japan	Sri Lanka
1.	Land size of the country	Weakness	Weakness
2.	Costal Population density	Threats	Opportunity
3.	Gini co- efficient	Opportunity	Weakness
4.	Human development index. (HID)	Strength	Weakness
5.	Political intervention for EW	Opportunity	Weakness
6.	Cultural impact for EW	Strength	Weakness
7.	Language impact for EW	Opportunity	Threats
8.	Use of different Type of messages to EW	Weakness	Strength
9.	Availability of very high sophisticated (Satellite etc) early warning methods	Strength	Strength
10.	Public response for new technological early warning	Opportunity	Opportunity
11.	Operational arrangement of new early warning system	Strength	Strength
12.	Reliability of new early warning systems	Strength	Weakness
13.	Maintenance and upgrades	Opportunity	Weakness
14.	Available conventional communication methods	Weakness	Strength
15.	Public response for conventional early warning	Weakness	Opportunity
16.	Operational arrangement of conventional early warning system	Weakness	Weakness
17.	Reliability of conventional warning systems	Weakness	Opportunity
18.	Contribution of electronic media for early warning	Opportunity	Opportunity

19.	Contribution of social media for early warning	Opportunity	Opportunity
20.	Contribution of other network for early warning	Opportunity	Strength
21.	Voice testing (Live testing)	Strength	Opportunity
22.	Communication testing (poll test)	Opportunity	Opportunity
23.	National level EW	Opportunity	Strength
24.	Subnational level EW	Strength	Strength
25.	Community level EW	Weakness	Opportunity
26.	Satisfaction of delivery and reception of EW messages	Opportunity	Opportunities
27.	Public awareness on warning mechanism	Opportunity	Opportunity
28.	Effectiveness of having early warning system and early warning	Strength	Strength
29.	Investment of early warning system	Strength	Strength

Table 19: SWOT comparison table

Considering the above table, all the weakness has to be strengthened, all the opportunities has to be changed to strength, all the threats has to be avoided or should be strength the other appropriate action to prevent the effect of threats and all the strengths has to be kept as it is or strength can be made more strength as shown in the bellow chart.

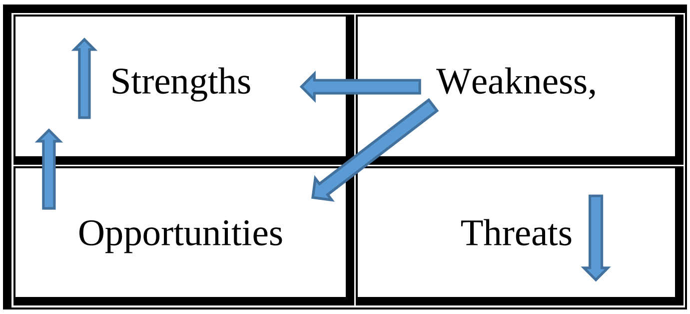


Figure 60: SWOT impact windows

Chapter V – Conclusion and Recommendations

5.1 Conclusion

A complete and effective early warning system comprises of four elements

i.) Identification of Disaster Risk, Sign and Threats

A complete early warning system should have a system to identify the impending disaster risk, sing and threats independently.

ii.) Timely Disseminate and Reception of Messages.

Identified disaster risk, sign and threats has to process to the valuable message and that message should have to disseminate timely and it should be verified the reception of relevant communities in the appropriate mechanism.

iii.) Efficiency of the Warning Mechanism

Efficiency of the early warning messages has depended on the time of dissemination and reception, accuracy of the message, short and clarity, community perception and acceptance and community respond.

iv.) Effectiveness of the system

The effectiveness of the system would be depended on number of disaster occurrence, availability of the system and reliability of the system.

The Early Warning Systems plays a major role in saving human lives and reduce economic losses caused due to natural disasters such as tsunami, earthquakes, floods, landslides, and other events. And it gives time for people living on risk areas to escape to higher ground, protecting themselves from falling objects and stopping trains before they are overtaken by these events. But it's important to start early warning systems in sustainable way for them to have a positive effect on the community on the long run.
Conduct communication drills with communities, governments, and experts should exchange information and ideas about potential risks. Communities should be able to understand the information delivered in the warning, while also being aware of the system's limitations.

Link with community-based activities, warning systems and other measures organized by communities may be particularly relevant in developing countries where government capacity and resources are limited. Start with low-cost systems: Start Warning systems with simple methods. Low-cost equipment, such as fire bells and sirens can be used. Also, government staff must understand communities' response to disasters to design warning systems.

Understand the limitations of technology: Although various technologies, such as tsunami simulations, communication systems, and earthquake monitoring are all needed to develop effective warning systems, their limitations must be taken into account.

Guidelines for quick decision making, disaster related organizations and government agencies should have a user manual or SOP for quick decision making. explaining when to disseminate the evacuation orders.

Understand communities, coping mechanisms, since warning systems are meant to benefit communities on the ground and to inform their actions, the responsible organizations should understand how local people cope with and respond to disasters. Community members decide on their own when, where, and how to escape. The organizations should tailor the contents of warning messages to the users' needs and points of view. Such messages need to be simple, timely, and encourage evacuation.

Establish uninterrupted systems, to ensure that warnings reach the communities at risk. Multiple communication channels should be established so that information keeps flowing in case of power and communication failures. (e.g.: SMS, loudspeakers, sirens. etc.)

Ensure services are available 24/7: Since natural events can happen at any time, the organizations concerned are required to function around the clock—24 hours a day, 7 days a week. Staff duty rotation should be arranged in the organizations.

With considering above four elements of the early warning system, the Japan has consisted all the four pillars. The japan has not depend on the other countries. But there are some gaps and constrain of the above mentioned four pillars and japan has to take adequate action to fulfilled the above given gaps and constrains.

With considering japan, Sri Lanka has many more gaps and constrains in the Early warning system even the above four elements have not fulfilled by the system. Identification of tsunami disaster, Sri Lanka is being depended on the regional and international technical agencies. There is no any independent technical system to issue the tsunami warning due to inadequate technology and money.

5.2 Recommendations

1. To make complete and effective early warning system should be inter-related with many elements, knowledge of hazards and vulnerabilities, education and training for people at risk, dissemination strategies and reception strategies as well as preparedness capacity to respond.
2. Responsibilities need to be clearly defined and people need to be well-informed and feel a degree of ownership of the implementation process. Much depends on establishing institutional capacities to ensure that early warning systems are well integrated into governmental policy and decision-making process. Focusing on early warning systems itself - show how communities can be involved in this process or how they can initiate the establishment of an early warning system at local level in connection with those at national, regional and international levels.
3. People-centered early warning systems is to be empowered individuals and communities exposed to hazards to act in sufficient time and in an appropriate manner

to reduce the possibility of personal injury, loss of life and damage to property and the environment.

4. Stakeholders comprising both information suppliers and information receivers should be made educated on all key elements of the end-to-end system and the relevant SOPs and communications which have to be complied.
5. Early Warning is the uttermost important thing. It has to be validated periodically.

a. Recommendations for Japan

1. Japan has to be developed a traffic plan and it should be integrated with the early warning system to ensure the evacuation of the vulnerable communities to avoid the traffic jam in high dense populated costal area.
2. When the earth quake magnitude is more than 07, the peoples in the 01 kilometer from the beach should be evacuated to the safer location with their vehicles within 05 – 10 minutes and if they unable to evacuate within given time, aware the people to evacuate without vehicles in order to avoid traffic jam.
3. The Japan has to enhanced the awareness of the early warning systems, channels, mechanisms and type and kind of early warning massagers which are going to be send the communities.
4. Japan is being disseminated several messages to general public and vulnerable communities. But each and every people could not be taken appropriate decision. In order to reduce this panic situation before the relevant time, Japan has to reduce the number of advisory, alert, warning messages. People do not need earthquake messages, magnitude, epicenter, etc. when consider the tsunami. Japan has to emphasized to the communities on evacuation message as soon as possible due to limited time for tsunamis.
5. Japan has to be improved the conventional communication system to response even during the night time. Early warning towers and other system could not be explained the evacuation locations and further additional details, in such situation conventional mechanism are important to guide the people until reach to safe locations. Therefore, Megaphone, public address systems etc, has to be ready in appropriate locations.
6. Japan has more than 60 % elderly peoples. They are taken more than 15 minutes to evacuate to the safe location by foot. Most of elderly and different abled people will die due to tsunami while they are moving to safe location and lack of awareness on early warning. In order to prevent such situation, Evacuation messages has to disseminated as soon as possible.
7. Japan has ordinary used Japanese language to warn the communities but japan has to take keen attention about foreign delegates who are working and living in the japan. Therefore, japan has to provided warning message at least English language even if they can provide message like “Tsunami, Tsunami, please Evacuate, Evacuate”. The people will response to that Message.

b. Recommendations for Sri Lanka

1. Sri Lanka has to build the dedicated communication system with the regional warning centers between the national tsunami warning center to avoid the communication interruption. Sri Lankan peoples could not get the earthquake feeling where Sri Lanka is not locating in the earthquake fault or Ring of fire.
2. Sri Lanka has cultural and social impacts for early warning specially language and giving night time evacuation order. The women cannot be seen in the night around 7pm due to transport barriers, less security, culture itself refuse to see the women in the night, dependence are not allowed etc, therefor Sri Lanka has to do the tsunami drill in the night time by using early warning system to avoid the such situation. Only the early warning

towers has provided messages by three languages. But each and every warning messages has to be disseminate by “Sinhala, Tamil, English” language in order to prevent the language barriers in Sri Lanka and thus each administrative levels have to be kept in ready the prerecorded warning messages to disseminate at the disasters.

3. Sri Lanka has been struggling with new technology involvement after established with the early warning system in 2009. Sri Lanka has to hired the technology from the original suppliers and it has to upgrade by time to time expending high cost. It is highly recommending to integrate with local technologies which can be sustained and effective by corporate with technical institutes.
4. The Sri Lanka has a well-established early warning system. Though it is well established, there is no any dedicated channel to conform the dissemination and reception of the message. Sri Lanka is being utilized many other channels which are military, police, etc. to overcome the current gap of early warning system. It is recommended to arrange a dedicated line with several locations to get the feedback of early warning messages.
5. After the great 2004 tsunami the word “TSUNAMI” is famous in the country. But science, aptitude of the hazard and many other response activates are not known by many other communities in the middle part of the country. Awareness on tsunami has to be provided and enhanced to the communities in order to save the life from future tsunamis.

5.3 Common recommendation to the world on early warning mechanism

1. ***In the past decade most of the peoples in the world has died by tsunamis due to lack of tsunami early warning system without concerning region, country, race, religion or any other factors. Most of countries they don’t have enough money to cover the entire area by warning systems. Some systems are very expensive. Some countries are doing business and earn large profit by selling early warning system. Most of the countries are struggled with the technologies. Therefore, it is recommended to identified and established a common early warning system(One system) for all countries such as digital HF communication system or satellite base communication system etc. to overcome the early warning issues in the world and save the lives form tsunamis.***
2. ***There are many warning systems exist in the word at the present. Many sirens, many colour codes are been using for communicate the warning information to the public. Therefore, it is recommended to standardized the sound that can be utilized as a Common sound for disasters such as ambulance sound. That common sound will help to identified the disasters in anywhere in the world and it can be integrated to mobile phones, radios, early warning towers, emergency response vehicles even during night time and also SMS alert for elderly people, foreigners.***
3. ***Create awareness among the communities to “improve their ability to judge the disasters” take appropriate action like “Kamaishi Higashi Junior High School” in japan 2011 tsunami respond.***

Chapter VI – Abbreviations & Reference

6.1 Acronyms and Abbreviations

ADRC	Asian Disaster Reduction Center
AEA	Atomic Energy Authority
AMPS	Analog
BOKUMI	Kobe City Volunteers for Disaster Management
CAO	Cabinet Office
CAP	Common Alerting Protocol
CB	Cell Broadcasting
CBO	Community Based Organization
CCCRMD	Coast Conservation & Coastal Resource Management Department
CDMA	Code Division Multiple Access
CEA	Central Environmental Authority
CEB	Ceylon Electricity Board
DDMCU	District DM Coordinating Unit
DEWN	Disaster Emergency Warning Network
DM	Disaster Management
DM Act	Sri Lanka Disaster Management Act No.13 of 2005
DMC	Disaster Management Centre
DMP	Disaster Management Plan
DoM	Department of Meteorology
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
EEWs	Earthquake Early Warnings
EOC	Emergency Operation Centre
EOC	Emergency Operation System
EPOS	Earthquake Phenomena Observation System
EW	Early Warning
EW	Early Warning
FDMA	Fire and Disaster Management Agency
FM	Frequency Modulation
GETET	Great East Japan Earthquake and Tsunami
GMDSS	Global Maritime Disaster and Safety System
GN	Grama Niladari (Final government administrative officer in the village)
GSM	Global System for Mobile communication
GSMB	Geological Survey & Mines Bureau
HF	High Frequency
HID	Human Development Index
ID	Irrigation Department

IGN	Intra Government Network
INGO	International Non-Governmental Organization
JMA	Japanese Meteorological Agency
LAs	Local Authorities
M	Meter
MASL	Mahaweli Authority of Sri Lanka
MDM	Ministry of Disaster Management
MEPA	Marine Environment Protection Authority
MLIT	Ministry of Land Infrastructure Transport and Tourism
MoH	Ministry of Health
NACWC	National Agency for Chemical wephone conventional
NARA	National Aquatic Resources Research and Development Agency
NBRO	National Building Research Organization
NCDM	National Council for Disaster Management
NDMC	National Disaster Management Centre
NDMCC	National Disaster Management Coordination Committee
NDMP	National Disaster Management Plan
NDRSC	National Disaster Relief Services Centre
NEOP	National Emergency Operation Plan
NGO	Non-Governmental Organization
NIDiP	Information Network for Disaster Prevention
NIED	National Research Institute for Earth Science
NIT	Nippon Telegraph and telephone company
NWC	National Warning System
NWSDB	National Water Supply & Drainage Board
PA	Public Address
S & R	Search and Rescue
SISCO	Security Identification System Corporation
SL	Sri Lanka
SLAF	Sri Lanka Air Force
SOPs	Standard Operating Procedures
TAC	Technical Advisory Committee
TWS	Tsunami Warning System
USGS	US Geological Survey
VHF	Very High Frequency
VPN	Virtual Privet Network
VR	Visiting Researcher

6.2 Reference Web Sites

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- Disaster Management Policy of 2014.
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- December 26, 2004: Asia - An earthquake measuring 9.0 on the Richter scale triggered the Boxing Day tsunami that struck 10 Asian and two African countries, killing almost 250,000 people. More than 170,000 of those who died were in Indonesia's Aceh province.
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Attachment 01- Questioner

アジア防災センター客員研究員プログラム（2016 年度）
ADRC Visiting Research Program (VR2016)

津波早期警戒に関するアンケート（日本）
Questionnaire on Tsunami Early Warning (Japan)

以下の質問について、あなたの日本の津波早期警戒に関する知識に基づいてご回答ください。
回答は、ゼロ（0）から十（10）のレベルでお答えください。（0）はそう思わない、（10）は非常にそう思う、（5）はその中間になります。5 未満は平均以下でまだ改善すべき点がある、6 以上は平均以上だがさらにより良くできる点があることを示します。
それぞれの質問に対して 1～10 のうちの数字をひとつ選んでお答えください。
いただいた回答は客員研究員プログラムの研究のみに利用します。また、回答は津波の早期警戒に関することについてお答えください。（その他災害は含まない。）

Please fill the following table based on your knowledge on Tsunami Early Warning in Japan.
Rank were arrayed from Zero to ten (0 – 10). Zero (0) = Dissatisfied, 10 (ten) = 100% Satisfied, 5 (five) = Average of Satisfaction. Bellow five (5) = Bellow average (need to be improved).Above five (5) = More than average but there are gaps to be fulfilled. You can use any one number for one question from I,2,3,4,5,6,7,8,9,10. (This values use for research purpose only.)   This is only for Tsunami Early Warning.

質問事項 Questions	Answers (Rank 0 – 10)
一般事項 General Information	
早期警戒情報に関する文化的な配慮が必要である。（ない場合は 10） Consideration of cultural impact/ issues on early warning is necessary (there is no impact= 10)	
早期警戒情報は日本語のみで発出されている。 Early warning is issued only by Japanese language.	
4 種類の早期警戒情報がある。（注意報、警報、避難、警報解除） There are four types of messages (Alert, Warning, Evacuation, Stand down)	
早期警戒のための新技術（衛星の利用等） New Technologies for Early Warning (satellite etc.)	
非常に高度で最新式の早期警戒システムが整備されている。 Very high sophisticated (Satellite etc.) early warning systems are available	
新技術を利用した早期警戒システムに対する住民の反応が非常に高い。 Public response for new technological early warning systems are very high	
早期警戒システムを運用する優れた仕組みがある。 There are excellent mechanism for operating the early warning system	
新しい早期警戒システムに対する信頼性がとても高い。 Reliability of new early warning systems is very high	
早期警戒システムのメンテナンスや性能向上がとても容易である。 Maintenance and upgrades of early warning system is very easy	
伝統的な手法による早期警戒（半鐘、旗などを使った標識など） Conventional Methods for Early Warning (bell, flag etc.)	
伝統的な情報伝達法がある（とても一般的である）。 Conventional communication methods are available (very common)	

伝統的な手法による早期警戒システムに対する住民の反応が非常に高い。 Public are very high response to the conventional early warning system	
伝統的な手法による早期警戒システムに対するとても信頼できる運用システムが存在する。 There is a very high reliable operational arrangement exist for conventional early warning system	
伝統的な手法による早期警報への信頼性がとても高い。 Reliability of conventional warning systems is very high	
伝統的な早期警報手法に関して頻繁にメンテナンスや性能向上が行われている。 Frequently maintenance and upgrades of conventional early warning are doing	
電子メディアやソーシャルメディア（ブログ、掲示板、Facebook、ツイッターなど）による早期警報 Electronic media and Social media (blog, bulletin board, Facebook, twitter, etc.) for early warning	
電子メディアは早期警戒情報伝達に非常に大きく貢献している。 There is very high contribution of electronic media for early warning dissemination	
ソーシャルメディアは早期警戒情報システムに非常に大きく貢献している。 There is very high contribution of social media for early warning systems	
その他の早期警報ネットワーク（自衛隊、警察等） Other Network for Early Warning (Self Defense Force & Police etc.)	
自衛隊や警察等、その他のネットワークが早期警報に利用されている。（4 つ以上ある場合を 10 とする） There are many other networks are using for early warning (More than 04)	
早期警報機器利用の演習や検査（新技術を利用した早期警戒システム） Rehearsals, Testing of Early Warning Equipment (for new technological EW system)	
週に一回音声演習やテストが行われている。 Weekly voice testing (live testing)	
週に一回情報伝達（データ通信）演習やテストが行われている。 Weekly communication testing	
各行政レベルの情報伝達 Different Administrative levels of warning dissemination	
国家レベルの早期警戒情報伝達システムがある。 There is a national level EW Dissemination system	
自治体レベルの早期警戒情報システムがある。 There are many sub-national level EW systems	
コミュニティレベルの早期警戒情報システムがある。 There are many community level EW systems	
早期警戒情報（注意報、警報、避難情報、警報解除）の発出のタイミングについて Timing for Tsunami Early Warning (Alert, Warning, Evacuation, Stand down)	
早期警戒情報の発出のタイミング（とても早い 10、とても遅い 0） Satisfaction of delivery of EW messages (All levels)	
早期警戒情報を受取るタイミング（とても早い 10、とても遅い 0） Satisfaction of reception of EW messages (All levels)	
津波早期警戒システムに関する啓発 Awareness of tsunami early warning system	
早期警戒システムについての住民啓発が提供されている。 Public awareness on early warning mechanism is provided	
早期警戒情報の効果 Effectiveness of Early Warning	
現在の早期警戒システムおよび早期警報はとても効果が高い Current early warning system and early warning is very effective	
早期警戒システムへの投資の費用対効果 Cost and benefit for the investment of EW systems	
早期警戒システムへの現在の投資額について妥当だと思う。 I am satisfied with current amount for the Investment of early warning system	

EW- Early Warning

年齢（Age）	20 才未満(20 or below) / 21-30/ 31-40/ 41-50/ 51-60/ 60 才以上(above 60)

性別（Gender）	男（male）／女（Female）
職業（Designation）	会社員(office worker)／公務員(government officer)／自営業(self-employed)／ 主婦(housewife)／学生(student)／無職(unemployed)／その他(others)

お忙しい中、ご協力大変ありがとうございました。
Thank you very much for your cooperation!
By J.M.A.R.Jayarathne (ジャヤラトネ)
ADRC Visiting Researcher（アジア防災センター客員研究員）

Attachment 02- Research Paper

Analysis of the Effectiveness of Early Warning System to Face Future Tsunamis in Sri Lanka by comparing with Japanese Early warning system.

J.M.A.R. Jayarathne, Deputy Director, Emergency Operation, Disaster Management Center, Ministry of Disaster Management, Sri Lanka, With ADRC Japan

Abstract

On December 26 2004, about 4/5 of the costal belt of Sri Lanka was affected by a Tsunami which occurred due to an earthquake off west coast of north Sumatra Islands. The location of the epicentre of this earthquake was at 3.2N and 95.82E at a depth of 30 km below mean sea level. The quake that occurred at 6:58:53 Sri Lankan time had a magnitude of 9.0 in Richter scale. Humans were confronted by an unprecedented catastrophe impacting the lives of people not only in the Indian Ocean region but all over the world. The death toll is believed to be over 270,000 people with billions of dollars in damage cost. It is widely acknowledged that if effective Early Warning System had been in place in the Indian Ocean region, thousands of people could have been saved. The present Early Warning System has designed for communicate from national level to district / divisional /Grama Niladhari levels.

The Early Warning towers, radio communication system, SMS and Cell broadcast system, fax, e-mail, inter government network, VPN line, social media are main sources of communication system already been established in the country. In addition to above communication system the police and military communication systems, media and the land line telephone systems are utilised directly and indirectly for communication and coordination of disasters. Main initiatives were taken by the Disaster Management centre which was established after the Tsunami in 2004. Over a decade, many systems and activities provided to enhance the Tsunami Early Warning System in Sri Lanka. Two times tsunami evacuations (2007 & 2012) and one Tsunami warning (2011) were issued after the 2004 up to now. A tsunami warning system (TWS) is used to warn coastal communities in advance and issue warnings to prevent loss of life and property damages. Meteorological Department which is national warning cater (NWC) issue the warning and Disaster Management Centre is being disseminate those messages from national level to local level.

The islands of Japan are located in a volcanic zone on the Pacific Ring of Fire. Destructive earthquakes, often resulting in tsunami, occur several times each century. The 1923 Tokyo earthquake killed over 140,000 people. More recent major quakes are the 1995 Great Hanshin earthquake and the 2011 Tōhoku earthquake, a 9.0-magnitude quake which hit Japan on March 11, 2011, and triggered a large tsunami. Due to its location in the Pacific Ring of Fire, Japan is substantially prone to earthquakes and tsunami, having the highest natural disaster risk in the developed world. Japan is a developed country thus the Sri Lanka is developing country. However, save the people in the world from the disasters that should not be the issue. Therefore, this study would be attempted to measure the effectiveness of the current systems of both countries and it will facilitate the future developments for the Tsunami early warning. The study was identified the issues in both countries and forwarded the recommendations.

Introduction

On December 26 2004, an earthquake measuring 9.0 on the Richter scale struck the western coast of Sumatra in Indonesia triggering massive ocean waves or “tsunamis”. Humans were confronted by an unprecedented catastrophe impacting the lives of people not only in the Indian Ocean region but all over the world. The death toll is believed to be over 270,000 people with billions of dollars in damage cost. Asian region and there was not any early warning mechanism to save the people lives. Therefore, more than 35,000 people were died in Sri Lanka. Because of that government establish the Disaster Management Centre (DMC) for coordinate with other stakeholders to prevention, mitigation, preparedness, training & public awareness and response in the impending disasters. One of the functions of the DMC has identified as community early warning and dissemination through the early warning systems. Therefore, DMC has been strengthening the early warning system by using various technologies such as establishing of early warning towers, supply of distribution of sirens and public addressing systems, SMS and cell broadcast system, etc. But prior to beginning of all these systems in Sri Lanka, there were traditional warning mechanism for various disasters. At the present all traditional and new technological systems are integrated to get the maximum benefit to the community early warning.

Mostly many developments and civilization is occurring in the coastal areas. Tourism industry is booming in the coastal areas. Therefore, to save the coastal communities, there should be a timely and effective early warring mechanism from the national level to the village levels. After the introduction of the early warning system around 10 years ago in Sri Lanka, it has not been validated. This research will facilitate to clarify the current issues and identify solutions in the early warning system in Sri Lanka with compare to the Japan.

It is widely acknowledged that if effective early warning systems had been in place in the Indian Ocean region, the death toll would have been drastically reduced While a relationship between local, felt earthquakes and tsunamis was realized in ancient times in many societies, it was much later in human history that it was realized that destructive tsunamis can propagate great distances, far beyond the range of human perceptibility of the causative earthquake. The present system of communication from national level to district / divisional / local authority / Grama Niladari levels or other specific identified locations is mainly through the Police and military communication systems, radio communication, multi-hazard early warning towers, media and the normal telephone systems. Alternative coastal wide communication systems already been established for the Tsunami disaster. Main initiatives were taken by the Disaster Management center which was established after the Tsunami in 2004.Over a decade, many systems and activities provided to enhance the Tsunami Early Warning System in Sri Lanka. 2 Tsunami evacuations (2007 & 2012) and one Tsunami warning (2011) were issued after the 2004 up to now. A tsunami warning system (TWS) is used to warn coastal communities in advance and issue warnings to prevent loss of life and damages. Meteorological Department issue the warning and Disaster Management Centre is catering all communications from national level to the local level but up to now No studies had conducted to evaluate the current early warning system for the tsunami disaster.
It is essential to ensure capacity of the Early Warning system to save more than 2 million lives along the coastal area of Sri Lanka. Gaps of disseminating and community reception at night time also been identified. But up to now there is no any studies had been conducted to evaluate the current early warning system for the tsunami disaster in Sri Lanka. It is essential to ensure the capacity of the Early Warning system is sufficient to save the people who are living along the coastal belt of Sri Lanka.

Japan is an island nation in East Asia. Located in the Pacific Ocean, Japan is an archipelago of 6,852 islands. The four largest islands are Honshu, Hokkaido, Kyushu, and Shikoku, which together comprise about ninety-seven percent of Japan's land area. With over 127 million people Japan has the world's tenth-largest population. They are primarily the result of large oceanic movements occurring over hundreds of millions of years from the mid-Silurian to the Pleistocene as a result of the subduction of the Philippine Sea Plate beneath the continental Amurian Plate and Okinawa Plate to the south, and subduction of the Pacific Plate under the Okhotsk Plate to the north. Japan was originally attached to the eastern coast of the Eurasian continent. The subducting plates pulled Japan eastward, opening the Sea of Japan around 15 million years ago.

Greater Tokyo Area, which includes the de facto capital city of Tokyo and several surrounding prefectures, is the largest metropolitan area in the world, with over 30 million residents. About 73 percent of Japan is forested, mountainous, and unsuitable for agricultural, industrial, or residential use. As a result, the habitable zones, mainly located in coastal areas, are highly populated. Making Japan as one of the most populated countries in the world. Japan's geographical and climatologically the country is vulnerable to frequent natural disasters such as typhoons, torrential rains and heavy snow as well as earthquake, Tsunamis and volcanic eruptions. Japan is located in the circum-Pacific mobile zone where seismic and volcanic activities occur constantly. Although the country covers only 0.25% of the land area on the planet, the number of earthquakes and distribution of active volcanoes is quite high. Due to the geological formation with plate boundaries of the Pacific plate, the Philippine Sea plate, the Eurasian plate, and the North American plate, Japan is substantially prone to earthquakes and tsunami, having the highest natural disaster risk in the developed world. Japan has well established disaster early warning system to response the impending disasters. Therefore, study has helped to compare the warning system with Sri Lanka.

Objectives

- To identify current issues in the early warning system in Sri Lanka and Japan.
- Identification gaps in the current Early Warning System and remedial measures for further improvements both countries.

Methodology

Data and information collected from the both countries. A survey data was gathered by using a questionnaire method that is utilized to correct, analyze and interpret the views of a group of people. All the information transfer in to the data which can be used. Data are analyzed by ranking method. Primary data were converted to the secondary data. Finally, the conclusion and recommendation could be forwarded through SWOT analysis techniques.

Data were analyzed by ranking analyzing method. Rank were arrayed from Zero to ten (0 – 10). Zero (0) = Dissatisfied, 10 (ten) = 100% Satisfied, 5 (five) = Average of Satisfaction. Bellow five (5) = Bellow average (need to be improved). Above five (5) = More than average but there are gaps to be fulfilled. In the other hand, it does imply the value from Zero (0) to ten (10) is equal to the 0% to 100%. Data will be analyzed by the descriptive statistics method such as Mean, Median, Mode, Range, Standard deviation etc. All relevant data will be compared by qualitatively and quantitatively. Percentage is used to describe the data proposition of the sample. In order to present the data, Pie charts, bar charts tables will be used. Analyzed the Gaps and consequences through SWOT.

Limitation of the Research

6. Time: Three months' period is not enough to gather the data with other works.
7. Field observation: Inadequate discussions has had with affected communities and relevant officers.

8. Literature review: Lack of available research on the early warning system.
9. Analysis: Simple analysis method has been used to discuss the result.
10. Inadequate questioner survey in the Japan in each prefecture.

Result and Discussion

Data were evaluated under the main section of Early Warning and Dissemination in the disaster management field. Result and discussion would be based on the questioner survey. Early Warning and Dissemination has further categorized into 11 sub field and it is indicated in the questioner thus giving more elaboration of the Early Warning field. In order to analyze the relevant data, it has to be divided to many sub areas. All the collected data were summarized and averaged. Averaged data were representing as percentage except the general information such as land size, population density and HDI. Both Japan and Sri Lanka data were displayed in the following tables with the detail discussion.

I. Evaluation of General Information to Early Warning

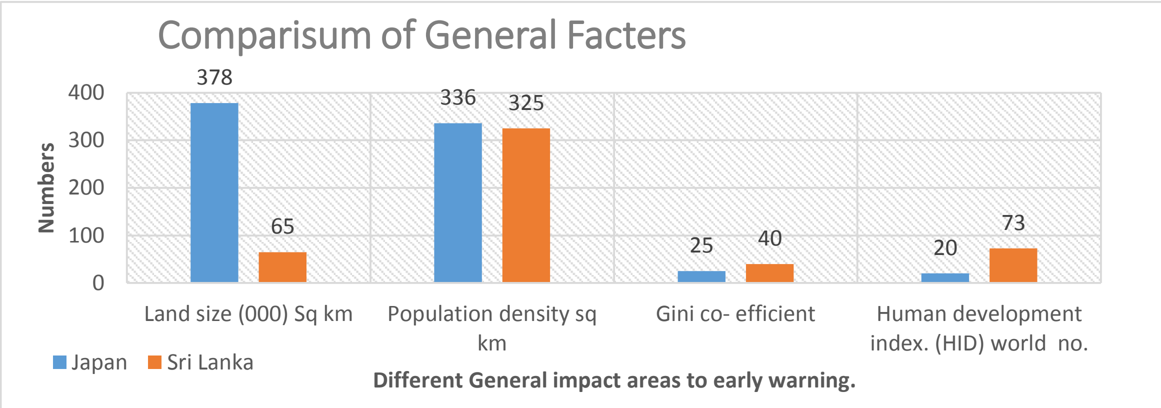

Figure 1: Comparison chart of General factors

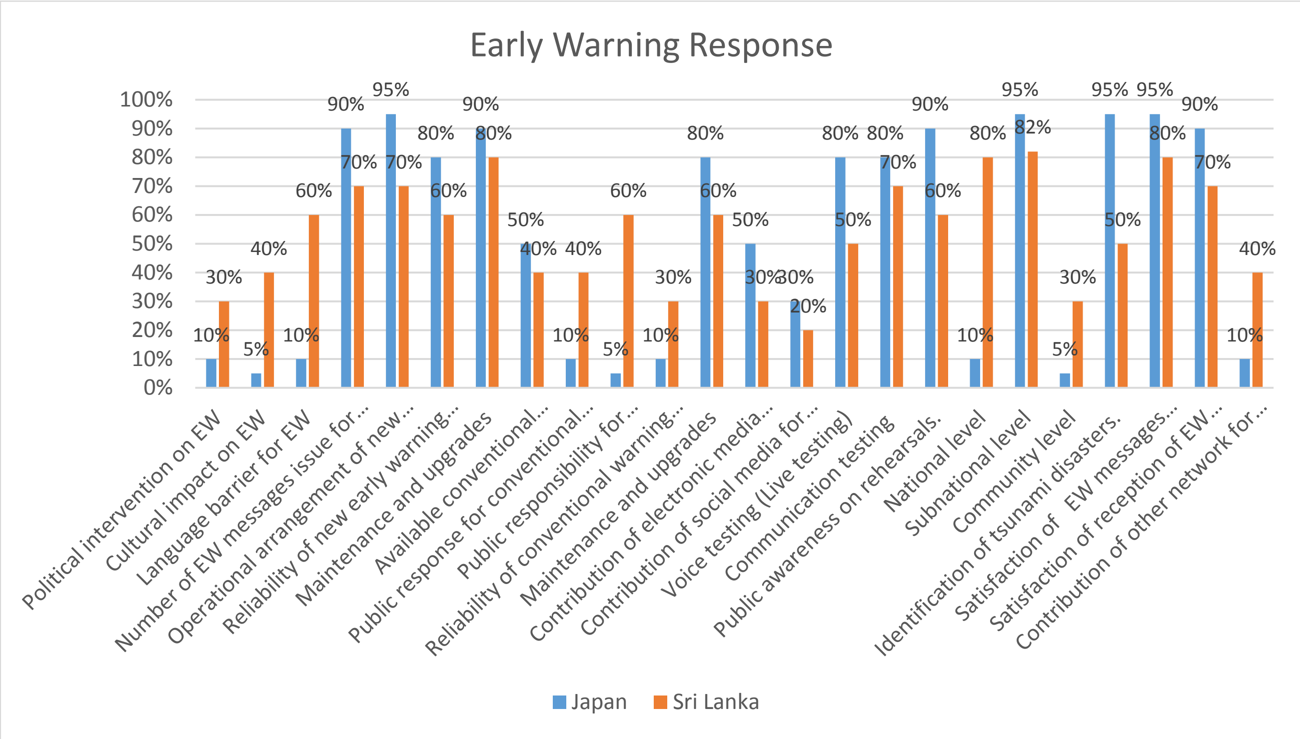

Figure 2: Factors affect to the Early Warning, Comparison chart

Japan is 06 time bigger than Sri Lanka. Cost line length of the Japan is 29751 Km while Sri Lanka cost line is 1340 km. It is 22 times bigger than the Sri Lankan cost line. Density is almost same. But Japan has high Population distribution in coastal area due to 70% land belong to mountainous and forest while Sri Lanka has 30% mountains and forest. Both the high cost line population and long length of the costal line of the Japan will be created the disadvantage for tsunami disaster early warning. There is a high frequency of chance to missing the warning of entire vulnerable costal belt thus if the one warning tower fail to disseminate warning will be affect more peoples in the vulnerable area due to high density of population in the costal belt. However, these facts can be ignoring with the available warning systems. Inequality of income is high in Sri Lanka. Life expectancy, Education and per capita income are high in japan it is rank no.20. This wealth also effects to the receive the warning due to unavailability of radios, television, mobile phones and internet facilities to some vulnerable communities in Sri Lanka. Political intervention to the early warning dissemination in Sri Lanka is bit higher than the japan. It is also effect to consume the timing of warning dissemination. Sri Lanka is multinational country therefore it has multi-culture. Many languages have been using in Sri Lanka specially Sinhala, Tamil and English. Sri Lanka has to pass the messages based on the culture and language in order to control the panic situation. For instance, east and the north of the country are majority of Tamils and the moor. Because of that disseminate the messages by Tamil languages is more effective. Also Sri Lanka is tourist country. All the costal belt is enriched with foreigners. Therefore, it is very important to pass the messages by English language too.

II. Use of New Technologies for Early Warning

Japan has Early warning systems based on the satellite operation. They have own satellite which is J-Alert. But Sri Lanka does not have any satellite. A few systems have operated by satellite technology which are early warning towers and Thuraya satellite communication. Japan is highly depending on these new technological early warning systems. Those systems are allocated to where it is vulnerable locations in the country. Japan has fully automatic warning system. Peoples in the Japan are highly response to the new technological warning systems like early warning towers. Sri Lanka also highly depend on the new technological early warning system but systems are not commonly available in the country. Only 77 early warning towers are available in costal belt in the country. Also Sri Lanka is being depending on the initial data and information which are forwarding by regional countries specially India, Indonesia and Australia. Though these new technological systems are reliable in both countries, Sri Lanka don’t have proper maintenance mechanism due to unavailability of such technological expertise in the country. This is big issue of Sri Lanka. Japan has their own technology, skill and, knowledge. However, the Tsunami is very rare in Si Lanka than Japan. In the past decade the only one tsunami has recorded in Sri Lanka while having more tsunami in Japan.

III. Use of Conventional Communication Methods for Early Warning (CCM)

Sri Lanka has mostly depended on Conventional Communication Methods due to lack of new technological systems. Sri Lanka has been highly responded to these conventional communication systems but it is depending on person to person and also the other factors which are environment, location, number of system available, kind and type of the communication system etc. This system also has depended on the national system because they cannot predict the tsunami. Therefore, they have to be alert on the national warning and information receiving system. If there is a gaps or failure in national system, entire conventional communicational system has failed. Due to low cost of operation and maintenance this CCM is very much popular in rural area in Sri Lanka. Japan has a very few systems are operations such as megaphone and public address systems. Japan has proper maintenance mechanism if the systems are existing. But it is very low reliability in both countries.

IV. Utilization of social media and electronic media for early warning

Japan has separate media channel for early warning and they can operate independently. Sri Lanka has depended on privet and government broadcasting and telecasting channels and those are not working at 24 hours’ basis. Both countries predominantly using but Sri Lanka has not proper mechanism to use this media during night time. Face book, twitter, WhatsApp, Skype, messenger, viber and other social media are being used by the both countries. But in the night no one has responded to getting warning from social media.

V. Use of Other Network for Early Warning (Military & police etc.)

Japan use their own communication system while Sri Lanka has been more utilized the other communication systems such as Military, Police, fire brigade, coast guard, railway etc. This is very reliable when the main system has fail the other alternative system has existed. Also peoples more confidence when it is coming more communication channels.

VI. Rehearsals, Testing of Early Warning Equipment

Japan has frequently testing of their communication systems by full strength. But Sri Lanka has not operated the system frequently in the full strength. Sri Lanka is being used poll testing method to test the early warning towers in order to prevent the panic. But it does not imply the workability of the voice dissemination of the warning towers. Both countries are being displayed the above average level in the testing of communication systems.

VII. Responsibility of Different Administrative levels for Warning Dissemination

Sri Lanka national government has higher responsibility to early warning dissemination at any time. Districts of Sri Lanka also has same responsibility to pass the message to the district level and community level. Sri Lankan village level communities have high responsibility to disseminate the early warning among their communities due to inadequate technological early warning equipment. Japan has each prefectures level early warning system to cater all the vulnerable areas in the country. But japan don't have any responsibilities to warn the people nationally. If Prefecture could not able to disseminate the national government pass the messages immediately through the broadcasting, telecasting and by using other communication techniques.

VIII. Evaluation of communication in the Tsunami Early Warning

Most of the time Japan Peoples can feel the earthquake. They have their own sign for tsunami disaster, the people can take the decision to move to safe location. Japan has direct delivery and receiving early warning mechanism without depend other nation. Japan has high technical body to analyze the situation. Sri Lanka also satisfied if the messages received on time but Sri Lanka has to be depend on the International body to get the tsunami warning. However, Sri Lanka has integrated early warning system pass the message as soon as possible to the vulnerable communities.

IX. Awareness of tsunami early warning system

Japan has an excellent awareness system among the public sector. Japan had several tsunamis in the past decade. This experiences also convenience to peoples in alert to the tsunami awareness. Therefore, most of the peoples know the tsunami. However, if the peoples know tsunami, they could not have about where to go, what time to go, what to bring etc. Especially they don't know about transportation arrangement. Therefore, all the peoples are come with their vehicles. That would be major issue in the japan. The japan warning system has not yet concern about this issues. Sri Lanka has to improve the public awareness on early warning mechanism with the all the communities. Only the coastal communities know the tsunami warning system. But the other communities should have also known the warning system in order to prevent the impact from tsunami disasters.

X. Effectiveness of Early Warning System

Both countries have given higher priorities on early warning systems to save the lives and properties. Effectiveness of the early warning system depend on the Quality of messages and the warning received by public. More tsunamis have to be happened in order to analyze the effectiveness of the warning system. If there is no tsunami effectiveness also zero. Therefore, Japan has high effectiveness why it is operated in 2011 tsunami successfully. But in Sri Lanka do not have any tsunami after the establishment of tsunami towers simply after 2004.

XI. Analysis of Cost and Benefit investment for EW Systems

Comparatively Sri Lanka also invested more than the return of investment to the tsunami early warning system. But Sri Lanka has only one experience in 2004 tsunami. Bu Japan has high vulnerability to tsunami. Based on the frequency of tsunami occurrence, Investment has focused on Multi hazards angle. Therefore, it can be used to any impending disasters.

XII. Available and usability of the Early Warning Methods

The following table has described the technological and conventional early warning systems that are used in the world and also it is display the magnitude of use in Japan and Sri Lanka.

No	Communication System	Japan	Sri Lanka

1	Land line telephones / CDMA	Common use	Common use
2	Early Warning Towers	Commonly using for every disasters	77 towers only. Use for tsunami and cyclone.
3	Satellites	Common use	Tower operation and very rare use for communication.
4	SMS	Always using for public at any network.	Use for selected costumes. Cannot operate all the networks.
5	Cell Broadcast	No in use	Fairly use but do not have confidence.
6	VHF/HF Radio	Common use	Moderate use.
7	Mobile Network	Common use	Common use. But in the disaster, network system jammed.
8	Television channels	24 hours channels	No 24 hours channel. During night time have to inform to start the telecast.
9	Radio channels	24 hours channels and separate channels are available.	No 24 hours' channel. During night time have to inform to start the telecast
10	Press media	Not enough time	Not enough time
11	Fax	Ordinary use	Only 15 minutes can use after that system jammed.
12	Email	Always using.	Selected personal only
13	Internet	Common use	Messages Upload but not common use.
14	By Vehicles – Announcements	Fire brigade, police vehicles and helicopters are used.	No helicopters used, police, military vehicles.
15	NGOs and CBOs	Not much involved	High involved.
16	PA Systems	Commonly fixed systems are being used.	Always used. Mobile Pa systems also use.
17	Mega phones.	Very common	Very common.
18	Hand Sirens	Not use	Ordinary use.
19	Electric Sirens	Common use	A very few use.
20	Temple and church bells	Not use	Common use.
21	Mosque PA system	Not use.	Common use
22	Riders/ Push Bicycle & Motor	Not use	Ordinary use.
23	Early Warning Committees (Door to Door)	Not prominent. No mechanism.	Committees are available. In the disasters cannot find the committee.
24	Flags and different colour cords.	Rare use	Ordinary use
25	Other institutional communication systems	Japan has dedicated line to communication. Therefore, not depend on other communication.	SL always depend on other communication system such as military, police, fire brigade etc.
26	Mouth to mouth.	Very rare	Higher relationship among the communities. Most common practices.

Table1: Available and usability of the Early Warning Methods

XIII. SWOT analysis

SWOT technique uses for analyze the strengths, weakness, opportunities and threats of the early warning mechanism in the japan and Sri Lanka.
The following table has displayed the comparison and different values of early warning perspective of view such as information dissemination, reception, operation, other indirect

impact of warning etc. between two countries and within the country. This table results also link with the

No	Information effect to EW	Japan	Sri Lanka
30	Land size of the country	Weakness	Weakness
31	Costal Population density	Threats	Opportunity
32	Gini co- efficient	Opportunity	Weakness
33	Human development index. (HID)	Strength	Weakness
34	Political intervention for EW	Opportunity	Weakness
35	Cultural impact for EW	Strength	Weakness
36	Language impact for EW	Opportunity	Threats
37	Use of different Type of messages to EW	Weakness	Strength
38	Availability of very high sophisticated (Satellite etc) early warning methods	Strength	Strength
39	Public response for new technological early warning	Opportunity	Opportunity
40	Operational arrangement of new early warning system	Strength	Strength
41	Reliability of new early warning systems	Strength	Weakness
42	Maintenance and upgrades	Opportunity	Weakness
43	Available conventional communication methods	Weakness	Strength
44	Public response for conventional early warning	Weakness	Opportunity
45	Operational arrangement of conventional early warning system	Weakness	Weakness
46	Reliability of conventional warning systems	Weakness	Opportunity
47	Contribution of electronic media for early warning	Opportunity	Opportunity
48	Contribution of social media for early warning	Opportunity	Opportunity
49	Contribution of other network for early warning	Opportunity	Strength
50	Voice testing (Live testing)	Strength	Opportunity
51	Communication testing (poll test)	Opportunity	Opportunity
52	National level EW	Opportunity	Strength
53	Subnational level EW	Strength	Strength
54	Community level EW	Weakness	Opportunity
55	Satisfaction of delivery and reception of EW messages	Opportunity	Opportunities
56	Public awareness on warning mechanism	Opportunity	Opportunity
57	Effectiveness of having early warning system and early warning	Strength	Strength
58	Investment of early warning system	Strength	Strength

Table 2: SWOT comparison table

Considering the above table, all the weakness has to be strengthened, all the opportunities has to be changed to strength, all the threats has to be avoided or should be strength the other appropriate action to prevent the effect of threats and all the strengths has to be kept as it is or strength can be made more strength as shown in the bellow chart.

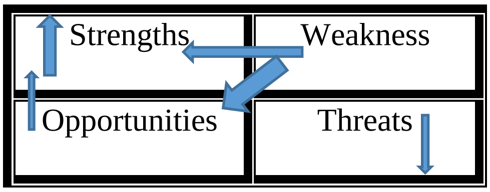

Figure 3 : SWOT impact windows

Conclusion and Recommendations

Conclusion

A complete and effective early warning system comprises of four elements

v.) Identification of Disaster Risk, Sign and Threats

A complete early warning system should have a system to identify the impending disaster risk, sing and threats independently.

vi.) Timely Disseminate and Reception of Messages.

Identified disaster risk, sign and threats has to process to the valuable message and that message should have to disseminate timely and it should be verified the reception of relevant communities in the appropriate mechanism.

vii.) Efficiency of the Warning Mechanism

Efficiency of the early warning messages has depended on the time of dissemination and reception, accuracy of the message, short and clarity, community perception and acceptance and community respond.

viii.) Effectiveness of the system

The effectiveness of the system would be depended on number of disaster occurrence, availability of the system and reliability of the system.

The Early Warning Systems plays a major role in saving human lives and reduce economic losses caused due to natural disasters such as tsunami, earthquakes, floods, landslides, and other events. And it gives time for people living on risk areas to escape to higher ground, protecting themselves from falling objects and stopping trains before they are overtaken by these events. But it's important to start early warning systems in sustainable way for them to have a positive effect on the community on the long run.
Conduct communication drills with communities, governments, and experts should exchange information and ideas about potential risks. Communities should be able to understand the information delivered in the warning, while also being aware of the system's limitations.

Link with community-based activities, warning systems and other measures organized by communities may be particularly relevant in developing countries where government capacity and resources are limited. Start with low-cost systems: Start Warning systems with simple methods. Low-cost equipment, such as fire bells and sirens can be used. Also, government staff must understand communities' response to disasters to design warning systems.

Understand the limitations of technology: Although various technologies, such as tsunami simulations, communication systems, and earthquake monitoring are all needed to develop effective warning systems, their limitations must be taken into account. Guidelines for quick decision making, disaster related organizations and government agencies should have a user manual or SOP for quick decision making. explaining when to disseminate the evacuation orders.
Understand communities, coping mechanisms, since warning systems are meant to benefit communities on the ground and to inform their actions, the responsible organizations should understand how local people cope with and respond to disasters. Community members decide on their own when, where, and how to escape. The organizations should tailor the contents of warning messages to the users' needs and points of view. Such messages need to be simple, timely, and encourage evacuation.

Establish uninterrupted systems, to ensure that warnings reach the communities at risk. Multiple communication channels should be established so that information keeps flowing in case of power and communication failures. (e.g.: SMS, loudspeakers, sirens. etc.) Ensure services are available 24/7: Since natural events can happen at any time, the organizations concerned are required to function around the clock—24 hours a day, 7 days a week. Staff duty rotation should be arranged in the organizations.

With considering above four elements of the early warning system, the Japan has consisted all the four pillars. The japan has not depend on the other countries. But there are some gaps

and constrain of the above mentioned four pillars and japan has to take adequate action to fulfilled the above given gaps and constrains.
With considering japan, Sri Lanka has many more gaps and constrains in the Early warning system even the above four elements have not fulfilled by the system. Identification of tsunami disaster, Sri Lanka is being depended on the regional and international technical agencies. There is no any independent technical system to issue the tsunami warning due to inadequate technology and money.

Recommendations

6. To make complete and effective early warning system should be inter-related with many elements, knowledge of hazards and vulnerabilities, education and training for people at risk, dissemination strategies and reception strategies as well as preparedness capacity to respond.
7. Responsibilities need to be clearly defined and people need to be well-informed and feel a degree of ownership of the implementation process. Much depends on establishing institutional capacities to ensure that early warning systems are well integrated into governmental policy and decision-making process. Focusing on early warning systems itself - show how communities can be involved in this process or how they can initiate the establishment of an early warning system at local level in connection with those at national, regional and international levels.
8. People-centered early warning systems is to be empowered individuals and communities exposed to hazards to act in sufficient time and in an appropriate manner to reduce the possibility of personal injury, loss of life and damage to property and the environment.
9. Stakeholders comprising both information suppliers and information receivers should be made educated on all key elements of the end-to-end system and the relevant SOPs and communications which have to be complied.
10. Early Warning is the uttermost important thing. It has to be validated periodically.

Recommendations for Japan

8. Japan has to be developed a traffic plan and it should be integrated with the early warning system to ensure the evacuation of the vulnerable communities due to high density of costal population and
9. When the earth quake magnitude is more than 07, the population of the 01 kilometer from the beach should be evacuated to the safer location with their vehicles within 05 – 10 minutes and if they unable to evacuate within given time, aware the people to evacuate without vehicles in order to avoid traffic jam.
10. The Japan has to be enhanced the awareness of the early warning systems, channels, mechanisms and type and kind of early warning massagers which are going to be send the communities.
11. Japan is being disseminated several messages to general public and vulnerable communities. Therefore, each and every people could not be taken appropriate decision. In order to reduce this panic situation before the relevant time, Japan has to reduce the number of advisory, alert, warning messages. People do not need earthquake messages, magnitude, epicenter, etc. when consider the tsunami. Japan has to be emphasized to the communities on evacuation message as soon as possible due to limited time for tsunamis.
12. Japan has to be improved the conventional communication system to response even during the night time. Early warning towers and other system could not be explained the evacuation locations and further additional details, in such situation conventional mechanism are important to guide the people until reach to safe locations. Therefore, Megaphone, public address systems etc, has to be ready in appropriate locations.

13. Japan has more than 60 % elderly peoples. They are taken more than 15 minutes to evacuate to the safe location by foot. Most of elderly and different abled people will die due to tsunami while they are moving to safe location and lack of awareness on early warning. In order to prevent such situation, Evacuation messages has to be disseminated as soon as possible.
14. Japan ordinary used Japanese language to warn the communities but japan has to take keen attention about foreign delegates who are working in the japan. Therefore, japan has to provided warning message at least English language too like “Tsunami, Tsunami, please Evacuate, Evacuate”.

Recommendations for Sri Lanka

6. Improve the dedicated communication system with the regional warning centers between the national tsunami warning centers to avoid the communication interruption. Sri Lankan peoples could not get the earthquake feeling where Sri Lanka is not locating in the earthquake fault or Ring of fire.
7. Sri Lanka has cultural and social impacts for early warning specially language and giving night time evacuation order. The women cannot be seen in the night around 7pm due to transport barriers, less security, culture itself refuse to see the women in the night, dependence are not allowed etc, therefor Sri Lanka has to do the in the night time by using early warning system to avoid the such situation. Only the early warning towers has provided messages by three languages. But each and every warning messages has to be disseminate by “Sinhala, Tamil, English” language in order to prevent the language barriers in Sri Lanka and thus each administrative levels have to be kept in ready the prerecorded warning messages to disseminate at the disasters.
8. Sri Lanka has been struggling with new technology involvement after established with the early warning system in 2009. Sri Lanka has to be hired the technology from the original suppliers and it has to upgrade by time to time expending high cost. It is highly recommending to integrate with local technologies which can be sustained and effective by corporate with technical institutes.
9. The Sri Lanka has a well-established early warning system. Though it is well established, there is no any dedicated channel to conform the dissemination and reception of the message. Sri Lanka is being utilized many other channels which are military, police, etc. to overcome the current gap of early warning system. It is recommended to arrange a dedicated line with several locations to get the feedback of early warning messages.
10. After the great 2004 tsunami the word “TSUNAMI” is famous in the country. But science, aptitude of the hazard and many other response activates are not known by many other communities in the middle part of the country. Awareness on tsunami has to be provided and enhanced to the communities in order to save the life from future tsunamis.

Common recommendation to the world on early warning mechanism

4. ***In the past decade most of the peoples in the world has died by tsunamis due to lack of tsunami early warning system without concerning region, country, race, religion or any other factors. Most of countries they don’t have enough money to cover the entire area by warning systems. Some systems are very expensive. Some countries are doing business and earn large profit by selling early warning system. Most of the countries are struggled with the technologies. Therefore, it is recommended to be identified and established a common early warning system (One system)for all countries such as digital HF communication system or satellite base communication system etc. to overcome the early warning issues in the world and save the lives form tsunamis.***
5. ***There are many warning systems exist in the word at the present. Many sirens, many colour codes are been using for communicate the warning information to the public.***

Therefore, it is recommended to be standardized the sound that can be utilized as a Common sound for disasters such as ambulance sound. That common sound will help to identified the disasters in anywhere in the world and it can be integrated to mobile phones, radios, early warning towers, emergency response vehicles even during night time and also SMS alert for elderly people, foreigners.

6. ***Create awareness among the communities to "improve their ability to judge the disasters" take appropriate action like "Kamaishi Higashi Junior High School" in japan 2011 tsunami respond.***

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